TOWN GEOLOGY:

THE LESSON OF THE PHILADELPHIA ROCKS.

STUDIES OF NATURE ALONG THE HIGHWAYS AND AMONG
THE BYWAYS OF A METROPOLITAN TOWN.

BY

ANGELO HEILPRIN,

Professor of Invertebrate Paleontology at, and Curator-in-Charge of, the
Academy of Natural Sciences of Philadelphia.
Author of "Contributions to the Tertiary Geology and Paleontology of the United States."

PHILADELPHIA:
PUBLISHED BY THE AUTHOR.
ACADEMY OF NATURAL SCIENCES.
1885.

IN presenting the following pages to the public the author lays no claim to having materially contributed to our existing knowledge of the geology of Philadelphia. His aim has been merely to so interpret many of nature's teachings as to render them readily comprehensible to the average mind, and to awaken that spirit for investigation which cannot but prove both pleasurable and profitable, and which, unfortunately, only too frequently remains dormant for want of proper cultivation. With this object in view he has omitted superfluous details, and the discussion of questions which are in the main still of a controversial character.

The observations recorded are almost exclusively such as have fallen to the personal notice of the author, although for many of the data bearing upon the history of the gravels and clays he is indebted to the writings of PROF. H. C. LEWIS, who has made a special study of the formation. The geological sketch map of the State of Pennsylvania is based upon a similar map prepared to illustrate an article by PROF. J. P. LESLEY for the "Encyclopædia Britannica."

A. H.

Philadelphia, May 15th, 1885.

CONTENTS.

I.

WORK, IN THE FIELD AND BY THE SEA; OR THE NATURE OF GEOLOGICAL INVESTIGATION.

Examine the open country after a rain; you will find the small streams that may be coursing over the meadow or down the hill-side turbid, the water no longer retaining its wonted transparency and purity. A certain quantity of earth or sand has been washed into it from the surrounding soil, and is that which gives the muddy aspect to the stream. Some of this impurity has been directly forced out by the impact of the falling drops upon the surface, while much of the remainder has been washed out by the running stream itself. Walk over a garden gravel patch after a shower, and you will note your feet sinking gently into the stony mass, as a grating murmur is thrown out by the gravel particles rubbing against each other. Here, the finer stone particles—the sand and earth—have been washed out from between the larger ones, and, consequently, the whole mass has been rendered "softer" and less resisting; that is, more latitude has been given to the pebbles to move about, or to be forced about. But manifestly, the

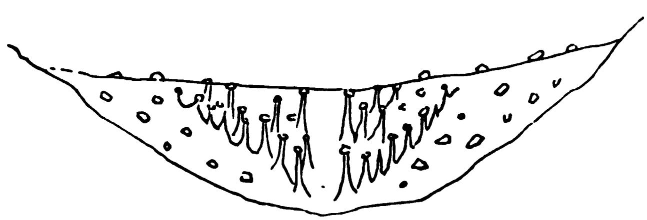
sand particles that may lie immediately beneath the individual gravel pebbles will be in a measure protected by them from the direct pluvial downpouring, and will, consequently, for a shorter or longer period retain their normal positions; whereas, the particles not so protected will at once yield to the attack of the battering rain-drops, and be removed by them to some other locality. It follows from this that little gravel-capped eminences will alternate with as many shallow depressions or pits, but unless your eye is well accustomed to minute details you will only notice a general looseness in the disposition of the gravel, or an unusual sharpness in outline, due to the washing away of a considerable part of the covering material. Follow the gravel walk up to where it passes under the projecting eaves of the house, and if you are sufficiently fortunate to find a pretty steady drip from the leaky waste-pipe above, you will experience no difficulty in distinguishing the little columns of sand and earth, each one capped with its tiny protecting gravel.

Conceive now that instead of gravel you are dealing with large blocks of stone or boulders, which may lie scattered about on the surface, or some distance beneath the surface, of the earth; and further, that the length of time during which the destroying agent, water, has been operating has been prolonged from a possible few minutes or hours to a period of years, or even centuries—what may be the result? Simply, that instead of having tiny sand columns capped by gravel pebbles, we may now have massive columns of earth topped by a series of rock capitals. Such is the origin of the famous earthen pillars of Botzen, Tyrol, where in hundreds they rise to heights of 20 to 100, or more, feet; and likewise, the similar structures that have been discovered in our

western territory, as in Monument Park, Colorado. Now, what

Natural Arch and Earth Pillars, Colorado.

is the full significance of these facts? Plainly enough, that the surface upon which the earthen pillars now rest rose at one time to the level occupied by the highest rock boulder, and that the reduction to the present lower level has been effected through the agency of water.



Formation of Earth Pillars.

We are here, then, taught an imposing lesson, and one that

cannot be too firmly impressed upon the mind of the intelligent observer. We are taught, in the first place, that the land surface is undergoing a constant and very remarkable modification in its relief, and secondly, that the prime agent producing this modification is water. With this conception of universal alterations firmly engrafted in our mind's eye, we are prepared to face the most striking teachings of geology. But let us pause a moment at an earth bank, and examine what is being done there during a rain. All over the surface you will probably notice streamlets of greater or less magnitude, tortuous or straight, coursing downwards, and either gathered up at the base into a primary stream, or continuing as so many distinct streamlets over the more level surface leading up to the bank. Watch the spot until the water will have run off, and you will note its place now occupied by dry water-courses, corresponding in magnitude with the streams which they represent. Some of these develop at the expense of others, and from what may have been originally an insignificant furrow we may have produced a gulley, of possibly several feet width and depth. And so we pass on from smaller to larger, until in course of time channels of very considerable magnitude are developed. Such is the origin of most of our ravines and gorges, some of which, like the Cañons of the west, attain to lengths of two or more hundred miles, and to depths of 5000–7000 feet; such is the smaller Cañon of Watkins' Glen, and the gorge through which the rapids of Niagara are hurled on to Ontario They are all the result of aqueous erosion—erosion that, at least in some instances, must have covered a time period of hundreds of thousands of years. Just what dimensions these excavations may have acquired, just so much material has been washed out of them. Let us pause

another moment here, and see what the exact outcome of all this means. It is manifest from the direction that flowing water takes that everything that is caught up by it must be removed to a lower level; hence, its destructive effects all tend to bring objects on the surface of the earth to lower levels than they formerly occupied. In other words, as aqueous destruction is universal, there must be everywhere a tendency toward a general leveling down of the surface.

Indeed, as practically everything that is carried down by the smaller streams is ultimately removed by the larger streams, the rivers, into the oceanic basins, so it must happen, granting no counter influences, that in a given time all surface inequalities will be reduced to one common level, which will be that of the sea. Just as the barest eminence may be removed within the space of a very few seconds, and a hillock in the course of a few hours, or days, or weeks, as the case may be, so just as surely, granting a sufficient length of time, will the bolder prominences, the proud mountains themselves, disappear one after the other to add their volumes to the dominions of the sea. Evidences of this destruction and of the "grand march to the sea" we see everywhere about us, in the smaller, no less than in the larger, channels that have already been described, in the pebbles and boulders that are strewn over every water-course, and in the mud or sediment that discolors so many even of our largest streams.

Not all streams are equally charged with sediment; but all streams, no matter how pure or transparent they may appear to the eye, contain a certain amount of impurity, which will be either chemically combined with the water, or simply mechanically suspended in it. The quantity of this impurity will depend upon the

character of the country traversed by the water. Where the rock masses most effectually resist the forces that tend to break them asunder, there, naturally, will there be the least outwash; where, on the other hand, the resisting force is weakest, there may we expect to find the greatest amount of derived sediment. Hence it is, that in certain regions, as the granites, and other crystalline rocks, the streams are very commonly singularly clear, whereas, at the same time, in other localities, as of limestones and sand-stones, they exhibit a remarkable turbidity. The Schuylkill River, which, with its tributary streams, drains a region of readily decomposing shales and sandstones—"Triassic sandstone"—appears in a yellowish livery after almost every heavy rain.

Take a sample of your river water when it is purest, and weigh it; take a sample of equal volume from the same stream when it is muddy, and weigh it also. Divide the difference between the two by the weight of the pure water, and you obtain the proportion by weight which the contained sediment bears to the water. This determination has been made for a number of prominent rivers of the globe, and we find that whereas this proportion in the Mississippi near its mouth is about the $\frac{1}{1500}$, in the case of the Po it is the $\frac{1}{150}$, and in that of the Vistula as much as the $\frac{1}{25}$ (maximum). The solid particles normally contained by the Schuylkill in its course between Fairmount and Pottstown constitute on an average about 10 grains to every gallon of water (18 parts in every 100,000); when unusually clear, this quantity is reduced to 7 grains. In the region of the Water Gap the Delaware contains but 3 grains to the gallon, whereas, in tide-water at Kensington the quantity not infrequently rises to treble this amount.

Indeed, in some of the South African water-courses the quantity

of sediment is so great as to render the streams true rolling masses of mud, through which a passage is only effected with difficulty. Having found out what proportion by *weight* our sediment bears to the water, it becomes easy to deduce from this the proportion by *volume*. The mud carried down by a river may be considered to weigh on an average twice as heavily as water; in other words, its specific gravity, as compared with water, is assumed to be in round numbers 2. Now, if, as in the case of the Mississippi River, the quantity measured by weight stands in the proportion of 1 to 1500, then, manifestly, the proportion by volume will be only one-half of this, or in the ratio of 1 : 3000. More accurately determined, this ratio is found to be 1 : 2900. Keeping this figure in mind, let us see what broad principle is enunciated by it. The Mississippi River discharges annually at its mouth no less than 19,500,000,000,000 cubic feet of water. Of this prodigious quantity the $\frac{1}{2900}$ part, as we have just seen, will be sediment; hence, the annual quantity of mud discharged into the Gulf of Mexico by that stream alone will be 6,700,000,000 cubic feet, or what would be enough to cover a square mile of surface to a height of 240 feet.[1] This, then, will also represent the annual loss to the river's drainage basin, whence the materials have been derived. The most competent authorities consider that the average annual waste or reduction of the Mississippi basin is about the $\frac{1}{6000}$ part of a foot; in other words, that the entire area of square miles drained by this mighty stream is lowered on an average one foot in every 6000 years. Whether this figure also approximately represents the work done by the other streams of America or not, it is as yet impossible to state, the observations on this point not being sufficiently advanced to permit of an absolute answer being given We will, however, assume for

one moment that it does; what does it signify? It gives us the key-note to a very interesting calculation. Humboldt, and others after him, have calculated that the average elevation of the North American continent is about 750 feet. Necessarily, therefore, if a general reduction of one foot is effected in every 6000 years, then in a period of some 4,500,000 years (750 × 6000), granting no counter influences, the entire continent will be washed to the level of the sea.[2]

We have advisedly on two occasions used the expression "granting no counter influences;" what did we mean by it? We intended to imply that there *were* certain forces—forces of upheaval, or, rather, producing upheaval—which in great measure tended to antagonize the effect of destruction or denudation. These will be considered later on.

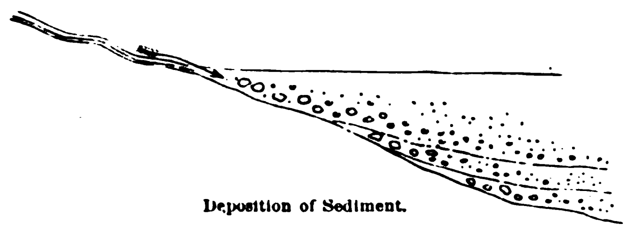
Let us now transport ourselves to the mouth of one of our rivers, and examine what is being done along the oceanic border. The first problem, possibly, that will strike our contemplative mind is the question: What becomes of the mud or sediment that is constantly being brought down by the rivers? The carrying power of water is dependent upon its velocity; thus, it has been shown that water flowing with a velocity of—

3 inches per second, barely produces any effect on fine clay;
6 inches per second, will raise fine sand;
8 inches per second, will raise sand of the coarseness of linseed;
12 inches per second, will sweep along fine gravel;
24 inches per second (or 1⅓ miles per hour), will carry pebbles of one inch diameter;
36 inches per second (or 2 miles per hour, which is only ⅔ the rate of an ordinary pedestrian walk), will sweep along angular fragments of the size of an egg.

The mathematical determination of this carrying process shows it to increase as the 6th power of the velocity; in other words, a stream flowing with a velocity six times as great as that of another stream will transport material weighing 46,656 times as much as the material carried by the slower stream. The moment that a running stream enters an area of aqueous stability, as a lake or oceanic basin, where no particular water currents manifest themselves, it meets with a sudden check, and in the slow diffusion of its waters with those of the foreign body, there will be a very perceptible diminution in the velocity of its current, which, in fact, soon ceases altogether. With this velocital diminution there will also be a precipitation of sediment, inasmuch as the retarded stream will now no longer be able to transport what it may have transported in its upper course, or where the current was very much more powerful. Hence, it results that along the mouth of every river there is formed a greater or less deposit of river mud, or sediment, whose gradual but steady accumulation is ultimately destined to choke up the river's own passage. It is by the building up of this material that a BAR, such as we know to exist near the mouth of the Delaware, or of the Hudson, is formed, and likewise, the mud-flats technically termed DELTAS. The principle that has here been enunciated of the dropping of mud in a tranquil basin can be studied without going to the seashore, however, for in the ordinary city reservoir and the feeding conduits we have precisely the same conditions presented as in the river and ocean. The reservoir not only acts as a receptacle for water, but also as a strainer, much of the impurity that is continuously washed in by the incoming waters being dropped to the bottom to form there a mud accumulation. Were it not for this happy disposition our

drinking water would be in a very much worse condition than it actually is, although this may be bad enough.

If we had the means of examining a deposit such as is forming at the mouths of all our rivers we should find that the disposition of its material was not a regular one; in other words, material of one kind would be found deposited at one place and material of another kind, at another place. The heavier substances, pebbles



Deposition of Sediment.

and gravel, will be thrown down nearest to the river's mouth, whereas, the finer material, such as the impalpable mud or fine sand, will be carried furthest out to sea. And between these two objective points we would have the material of intermediate grade. Precisely the same disposition holds with the material that is constantly being torn from the shores by the ocean, and which is being deposited in a continuous line along the coast border—the coarse pebbles or boulders near the land, and the finer particles out to sea.

The rivers and seas, then, are doing a common work in accumulating shore deposits. In these deposits, doubtless, many of the lower animals, such as the shell-fish, star-fishes and worms, of one kind or another, would find a congenial home, while, again, others would accidentally be washed into them. Toward the river side we would have a mixture of animals belonging to both fresh- and salt-water, or such as by their organization are adapted to both conditions

(brackish), while along the ocean border we should meet with almost exclusively marine types. Now, if by some means these deposits were elevated above the sea-level, what history would they unfold? In the first place, the regular layers or beds (strata) in which they would appear placed one on top of the other, holding a direction nearly parallel with the horizon, would suggest an even, and possibly long continued, deposition of sediment or mud beneath the water's surface. Layer has been laid upon layer, and the rock structure brought about which by the geologist is technically termed STRATIFICATION. Such a stratification is almost conclusive evidence of water action, and therefore, whenever we find rock masses showing this disposition in their arrangement, we are pretty confident in asserting that they were originally deposited in water. The horizontal position, again, of the beds we have been considering would indicate that no disturbance of any moment had overtaken the rocks since their deposition. They may have been tilted a little more on one side than on the other, but their normal condition has not been materially affected. Such gentle incline as they possess may, indeed, represent the slope of the ocean floor upon which the beds were primarily laid down, for, as a matter of fact, we do find that the oceanic bottom slopes off very gradually from the continental coast-line, carrying with it the slope of the beds that are deposited upon its surface. East of New Jersey, for example, for a distance of about 100 miles out to sea, the average gradient is not more than five feet to the mile. But we have still two factors to deal with in our consideration—the pebbles and the organic remains—what do they teach? The pebbles indicate pretty conclusively that that portion of the formation wherein they occur was deposited not very far from the coast-line, for as we have already seen, the

coarse material that is derived from the wear and tear of the continents is dropped by the water in close proximity to the shore. This fact is shown up to us by every pebbly or "shingle" beach, where the pebbles are washed up and down a regular line, whereas the finer particles, sand and earth, are carried considerable distances out to sea. A pebbly deposit, then, is *prima facie* evidence of littoral conditions. Finally, as to the organic remains, their history is a very clear one. We recognize in them forms that inhabit the sea, and we conclude that the deposit in which they occur was laid down in the sea. At one point or locality there may be a large intermixture of organisms that are by habit fresh-water, and we argue from them that the formation characterized by them must have been formed not very far from the embouchure of a river, where fresh and salt (brackish) water, and the accompanying organisms must have been indiscriminately washed together. Again, it may happen that only fresh water organisms are met with, and we conclude that we are dealing with an exclusively fresh-water deposit Such is the varied history which a geological chapter unfolds, and such the line of evidence which the geologist seizes hold of in order to decipher the conundrum of the rocks.

But thus far we have been dealing with hypotheses; we have assumed such and such formation lifted from the sea and presented to our gaze, and from it we have made our analyses. Now, what evidence have we that conditions like those which we have represented actually existed? Where is the proof that what was at one time under water is now laid high and dry? Where have we indications of ancient beaches?

Come with me to the locality known as Mullica Hill, an unpretentious hamlet town of New Jersey, some twelve miles S. W. of

the city of Camden. Just before entering the town from the Wenonah road we descend by the high bridge to the left, and in a minute or two stand opposite a rather unsightly bank or hillock, whose steep slope is deeply tinged of a reddish or ochrey color, the result of iron oxidation. On top of this bank, just underlying the soil, you will meet with a thick crusty layer, from which a sharp blow of the hammer will readily disengage a number of curious-looking objects, some of which you will have no hesitation in comparing with an oyster. They are, in fact, oysters—true, of a different species from those living at the present day, but oysters, nevertheless—and they occur in a genuine oyster bed, very much in the style and habit of the oyster of the Chesapeake and elsewhere. They have not been placed there by pilgrims either, contrary to what Voltaire might have supposed, as you will soon determine to your satisfaction; indeed, if you searched the seas over you would probably not find a single oyster of the form that is here found so abundantly in the hill. We have here no alternative; we are forced to the conclusion that the patch of land upon which we stand was at one time submerged beneath the sea, that at the period of submergence one or more oyster colonies established themselves as "banks," and that finally, patch and bank were lifted high and dry, just as we now see them. This is our first proof. But where are the evidences of stratification to which we referred as characterizing water made deposits? Such as may have originally existed are now completely shut out from view by reason of the continuous down-wash along the face of the hill, but if we journey round about three-quarters of a mile further to the east, and descend into what are known as Stratton's marl-pits, we will meet with a beautiful illustration of the structure in ques-

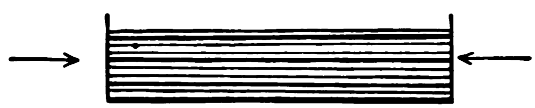
tion. Here, distinct layers or strata of variously colored sands and earths are very clearly exhibited lying one on top of the other, and occupying a very nearly horizontal position. More accurate determination, however, makes them incline gently in the direction of the sea, or to the southeast, and the geologist says that the beds DIP to the southeast. The inclination is so moderate, 25–40 feet to the mile, that it is barely appreciable to any but a practiced eye. Here, as at Mullica Hill, we also find the remains of numerous organisms (fossils) embedded in the rock masses, so that in addition to the evidence brought forward by stratification proving these deposits to have been at one time submerged beneath the water we have the additional evidence derived from these remains.

The materials of these so-called greensand marls are of a very fine consistency, and in many respects recall the somewhat similar formation which is being laid down in the open seas some little ways out from the immediate coast-line. We have here no pebbly deposits, so that as far as this kind of evidence goes, we have no indication of being near an ancient beach. But that broad white stratum situated about half-way to the top, and densely packed with the remains of the oyster known as *Ostrea vesiculosa*, warns us that the ancient shore-line could not have been very far distant; for if the habits of our antique oyster were at all like those of its modern successor, and we have no reason for believing that it was otherwise the case, then the animal must have lived in close proximity to the land. Indeed, this same oyster bed can be traced to considerable distances both northeast and southwest of the point where we are standing, from which we conclude that the borders of the former sea conformed in the same direction, and may have been

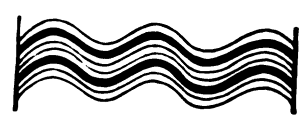
removed only a very few miles. Recrossing the Delaware, and passing out of Philadelphia by one of its northwardly trending avenues, the traveler finds himself in an entirely different region of rocks. He notes in the first place that the rocks are of a much firmer texture, being compact and solid, and not of the loose structure which we recognized in the New Jersey greensands; it may be inferred from this circumstance that the Philadelphia rocks are very much the older of the two, the additional length of time of their existence having materially tended toward their solidification. While the actual fact of antiquity holds good in the present instance, yet the nature of our inference is not a perfectly sound one, inasmuch as the matter of solidification is determined by a combination of circumstances, and does not depend merely upon the question of age. Solid rock masses occur all over the world of a very much more recent date than the New Jersey greensand, and, again, loose material is occasionally met with far antedating some of the more solid deposits about Philadelphia. The second peculiarity attaching to our rocks is a very striking one. The beds or strata of which the series are composed instead of being disposed in horizontal fashion, now lie at angles steeply inclining to the horizon. In some places, as in Potts' marble quarry, the inclination or dip is some 35–40 degrees; in other places, as, for example, along the Schuylkill near Lafayette, the strata are practically vertical; and, again, in still other places the strata appear in wavy lines or convolutions, dipping down now on the one side, then on the other. This last structure is beautifully seen at many points in the Park, and perhaps nowhere to better advantage than along the Wissahickon bridle-path, some few minutes beyond the new Reading Railroad bridge. Now, how do

we account for this anomalous structure? Surely it cannot be that the beds were originally deposited in a more or less vertical condition, nor can we conceive of their having been laid down in a series of undulating folds. There is no instance of rocks forming in our own time being deposited in either of the two methods here indicated.

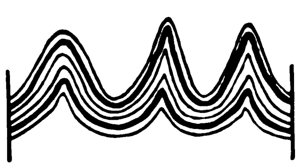
Hence, we are irresistibly led to the conclusion that something must have happened to these rocks since the period of their first formation—something that displaced their original horizontality, and threw them into the positions which they now occupy. This something was evidently a force of upheaval or compression, or a combination of both. Take a number of napkins, and lay them horizontally one on top of the other on a flat surface. Place a



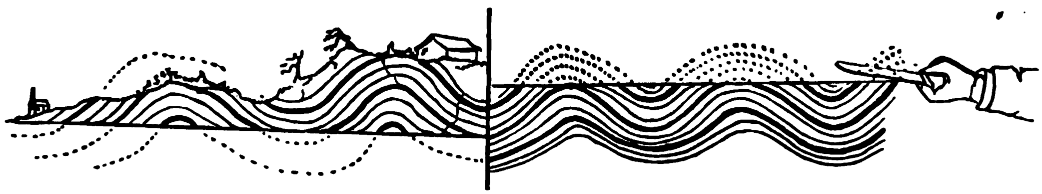
light board on top, and apply pressure from two opposing sides. What will be the result? The napkins will be forced up into a series of folds or convolutions, very much in the manner of some of our Philadelphia rocks. The undulations will be gentle or steep, and far removed or



closely packed, depending upon the force of compression that has been used. Repeat the same experiment with layers of plastic clay or wax instead of napkins, and apply, if possible, such pressure as will bring about a sharp flexure in the folds. With some sharp



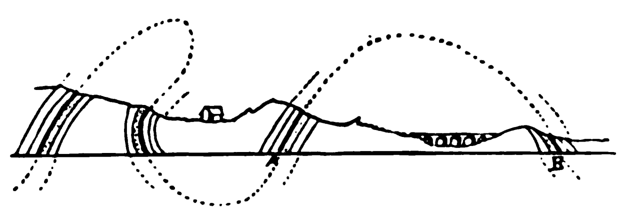
instrument divide now the mass along a horizontal plane somewhere about the middle, and remove the upper half. What have we? Layers of clay, dipping steeply to one side, then to the other, with broken or discontinuous edges on top.



Foliation and Erosion in their Relation to Rock Structure.

The resemblance between this structure and that of the steeply dipping rocks where there is no apparent folding will readily suggest itself. We have here, then, a very simple combination-method, by which, out of primarily horizontal layers, the two positions characteristic of our Philadelphia rocks can be brought about. It now remains to be seen to what extent this method is analogous to that which has been employed by nature in bringing out her own results. First, as to the force of compression. Physicists tell us that at an early period in the history of our planet, millions of years ago, the interior was in a more or less fluid condition, and that over this fluid or molten interior was formed the first crust. As the process of cooling went on layer after layer was added to this crust, until at the present time it would appear not improbable that the whole mass of the earth was practically solid to the centre. As matter in a liquid and heated condition occupies more space than when cooled and solidified, it is manifest that during the period of the earth's steady solidification there must have been a more or less continuous contraction of the planetary mass, which contrac-

tion, in the nature of things, must have been accompanied by corresponding shrinkages in the developing crust. But a general shrinking of the crust could only be brought about by the puckering up or folding of its substance, and this is precisely what has taken place. Here we have the explanation of the convolutions which we meet with all over the earth's surface, and which, large or small, testify to the intensity of the force that has brought them about. Having satisfied ourselves as to the manner in which rock-folding has been produced, it would not be difficult to conceive of the second structure—*i. e.*, the steep dip without apparent folding—if we could by some means imagine a natural slicing process somewhat similar to that which was employed in our experiment with the clay. Nature solves the mystery in the small drops of water to which reference was made in the opening lines of this chapter. Each individual inclined stratum, whether dipping at an angle of 45° or in the vertical, is a section of a curve or fold, whose arc, possibly extending over thousands of feet altitude, has been removed in the lapse of time through the never-ceasing eroding action of water. This is truly a vast conception, and one that might readily stagger belief, were it not for the numerous facts, all tending in one direction, which leave no room for doubt in the



matter. Suppose that at a given locality in one of your geological rambles, as at *A* in the accompanying diagram, you meet with a rock

layer, well defined in its relations to the rock masses lying on either side, dipping in a certain direction, say N. W.; and further suppose, that a similar rock, with precisely similar relations on either side of it, were found at another locality on the line of your journey, as at *B*, dipping in the contrary direction, or S. E.; what would be the inference, knowing the character of the forces that are and have been operative in nature? Naturally enough, that the opposingly dipping strata are sections of what at one time was a continuous whole, whose bond of union, the connecting arch, had by some means been removed. The identity of the mineralogical structure in question, together with the relations which they hold to the rock masses surrounding them, would force this conclusion upon us; but apart from this evidence we very frequently have evidence of a still more substantial character—namely, in the correspondence of the contained organic remains, if any such exist.

Having once satisfied ourselves of the capabilities of aqueous action, of the vastness of the erosion that has progressed through a period of untold ages, we no longer have difficulty in reconstructing the lost parts, and in picturing to our eye the restored landscape. We are prepared to admit that above the summits of what may now be low hills, thousands of feet of rock may have at one time existed, and are the less surprised to learn that, in ages gone by, mountain peaks, rivaling, if not exceeding, the Mont Blanc in altitude, may have constituted the ancestors of the present humble elevations of Fairmount Park.

II.

THE SUCCESSION OF LIFE.

Having so far mastered the principles of geological inquiry, we are in a measure prepared to face the problems that are presented to us at our doors. Geologists tell us that the rocks immediately about Philadelphia belong to several distinct series, or "geological formations;" they say, for example, that the rocks forming the depression of Montgomery and Chester Valleys belong to the "Silurian formation;" that the red rocks about Norristown are "Triassic;" that the clay deposits on the east bank of the Delaware, as well as the greensands that are so extensively dug for fertilizers further inland, are "Cretaceous;" and so on. Now, what do we understand by this term formation, and what significance has it in any geological inquiry? Most persons are familiar with the terms very generally adopted by historians to indicate certain epochs of time in the history of the inhabitants of the globe; we understand approximately, even if not accurately, what is meant by "ancient," "mediæval," or "modern," and when special reference is made to events having occurred in either or all of the historical periods so designated, we feel that our mind has

received some general conception of the chronological order in which these events succeeded each other. And so with all the minor indicators of time. Now, precisely the same significance attaches to the geological terms to which reference has been made. They are time-indicators in the history of the physical development of the earth, and if they fail in themselves to fix any *absolutely* determinable period of time in such development, they, nevertheless, determine with precision a *relative* sequence of periods directly comparable to those of the historical scale. "Silurian," "Triassic," and "Cretaceous" are to the geologist what centuries, or other epochs of time, are to the historian. The question may here naturally suggest itself, What is there to indicate a succession in the events of geological history? In what consists the proof that one series of deposits, or formation, is older (or newer, as the case may be) than another? History has its well-authenticated narrative, but geology has no such source whence to draw her information; and yet the proof of succession is practically just as absolute in the one case as it is in the other. Let us examine the problem in its simplest form.

It has already been intimated that at the mouths of all rivers the sediment brought down and discharged into the sea is deposited in a series of superimposed layers. It stands to reason from the manner of deposition that the top layer is that which has been deposited latest, and is consequently newest in time; the layer next below this is second in time, or next newest; and so on, until the last of the series, which will be the oldest. Conceiving these deposits forming in the sea to be lifted high and dry, as we have already seen must have been the case with stratified rocks generally, we should have presented in the succession of layers a

true index of their chronological development. The top stratum would be the newest in time, the bottom stratum the oldest, while those of intermediate position would represent intermediate periods of time. And such is precisely the history of all the horizontally stratified rocks with which we are acquainted. And even in cases where the rock masses no longer retain their original horizontality, and where the layers or strata lie to each other's side rather than directly one on top of the other, we can still trace, by following the line of slope, the older layers underneath the newer ones, and thus determine their relative antiquities. Here, therefore, we have our first absolute proof of a succession in geological time. It is only when the rock masses stand vertically on their edges, or when through some convulsion they have been so bent or twisted upon each other as to leave considerable doubt in the mind of the observer as to what is truly uppermost and what lowermost, that the geologist requires evidence beyond that indicated by the succession of the layers themselves. Let us look into the nature of this evidence. Anyone who has closely watched the marine life of our coast, say from the mouth of the James River in Virginia to Massachusetts Bay, will have been struck by the very general similarity which exists between the forms representing any given locality of that coast line and those of any other locality. Differences unmistakably do occur, but these are ordinarily of such a nature as not to disturb the general sense of identity uniting the whole. And this comparison between faunas may be extended southward and northward, toward the tropics and toward the poles, and yet the mind cannot readily rid itself of the impression that it is dealing with a single faunal unit. So, likewise, if we compare the marine fauna of eastern North America with that of Europe,

and this with the Californian, or the Japanese, we are struck with the same general resemblances everywhere. We recognize in the faunal assemblage of the day a distinct type, and this type, as determined by its component elements, recurs at practically all parts of the earth's surface. It may here be asked: Has this particular type of marine fauna always so existed, or has it been preceded in time by faunal assemblages of a somewhat different character? The geologist is now in a position to affirm that from the earliest to the present time there have been constant and repeated modifications in the physiognomy of the organic life of the globe. Groups of organisms that existed at one period of the earth's development no longer existed at another; old forms disappeared, while new ones were introduced, and thus a continuous alteration in the faunal type was effected.

It is further known that this faunal modification was a progressive one; that is to say, from a primitive assemblage of comparatively lowly organized types we pass on to types of higher and higher grades of organization, until at the present time it may be strictly said that the structural type is the highest that has ever been attained. It is also known that the modification here referred to belonged to no particular geographical area, but to all parts of the earth's surface; and that practically all parts of the earth's surface passed in equal, or nearly equal, periods of time through like modifications in the structural type of their animals. It is from a knowledge of these facts that the geologist is enabled to state, that a faunal assemblage characterizing the rocks of any one locality is the equivalent, as an indicator of time, of a similar faunal assemblage of any other locality; in other words, similar faunas indicate equal epochs of time in the physical development of the

earth, and, therefore, determine "synchronism" in the formations which they represent. We find in the various rock deposits of North America a repetition, more or less close, of the animal forms found in the deposits of Europe; these are found repeated again, at least in part, in South America and Asia, and their recurrence has also been noted in Africa and Australia. We argue, therefore, that the same periods of geological time are indicated by the rocks of North America as by those of. Europe; and, similarly, by the rocks of South America and Asia as well. It is found, moreover, that a given faunal assemblage always holds the same general relation to all other faunal assemblages in one locality that it does in any other; in other words, if a fauna, which we shall for convenience designate A, of a certain rock formation underlies another fauna, B, then the relative positions of these two faunas, wherever they exist, will be found invariable. The position of B will always be above A, unless in cases, such as we have already indicated, where the rocks may have been completely overturned. And similarly, if fauna B in any one locality underlies D or X, so will it in every other locality so underlie them. It is from this constancy in the position of the old-time faunas that the geologist has built up his chronological standard.

Geologists recognize the following divisions of time in their chronological scale:—

	Epochs and Formations.	Faunal Characters.
CAINOZOIC OR TERTIARY.	POST-PLIOCENE. Glacial Period.	Man. Mammalia principally of living species. Mollusca exclusively recent.
	PLIOCENE.	Mammalia principally of recent genera—living species rare. Mollusca very modern.
	MIOCENE. OLIGOCENE.	Mammalia principally of living families; extinct genera numerous; species all extinct. Mollusca largely of recent species.
	EOCENE.	Mammalia with numerous extinct families and orders; all the genera and species extinct. Modern type Shell-Fish.
	Laramie.	Passage Beds.
MESOZOIC OR SECONDARY.	CRETACEOUS. Chalk.	Dinosaurian (bird-like) Reptiles; Pterodactyls (flying Reptiles); toothed Birds; earliest Snake; bony Fishes; Crocodiles; Turtles; Ammonites —Deciduous Trees.
	JURASSIC. Oolite. Lias.	Earliest Birds; giant Reptiles (Ichthyosaurs, Dinosaurs, Pterodactyls); Ammonites; Clam- and Snail-Shells very abundant; decline of Brachiopods; Butterfly.
	TRIAS. New Red Sandstone.	First Mammalian (Marsupial); 2-gilled Cephalopods (Cuttle-Fishes, Belemnites); reptilian Foot-Prints.
PALEOZOIC OR PRIMARY.	PERMIAN.	Earliest true Reptiles.
	CARBONIFEROUS. Coal.	Earliest Amphibian (Labyrinthodont); extinction of Trilobites; first Cray-fish; Beetles; Cockroaches; Centipedes; Spiders.—Luxuriant land Vegetation.
	DEVONIAN. Old Red Sandstone.	Cartilaginous and Ganoid Fishes; earliest land (snail) and freshwater Shells; Shell-Fish abundant; decline of Trilobites; May-flies; Crab—Land Vegetation.
	SILURIAN.	Earliest Fish; the first Air-Breathers (Insect, Scorpion); Brachiopods and 4-gilled Cephalopods very abundant; Trilobites; Corals; Graptolites.
	CAMBRIAN.	Trilobites; Brachiopod Mollusks.
AZOIC.	ARCHÆAN. Huronian. Laurentian.	Eozoön (probably not a fossil).
	PRIMEVAL.	Non-sedimentary.

The PRIMEVAL or oldest rocks would naturally embrace such as were first formed—in other words, the rocks of the primitive crust; but whether rocks of this nature are actually visible at the present time on the surface of the earth may be considered doubtful. The ARCHÆAN are the oldest of the sedimentary series (or such as were laid down by water as the result of wear and tear upon an earlier land-surface) with which we are acquainted. They show no unequivocal evidences of organic life in their midst, although, doubtless, both animal and vegetable organisms had already come into existence at that early period. The life of the succeeding CAMBRIAN period, as is indicated by the fossil remains, must have been both numerically, and in the variety of forms, a rich one, but the types represented appear to have belonged exclusively to the Invertebrata, or animals wanting in a vertebral column. The shell-fish (Mollusca) and crustaceans (Trilobita) are pre-eminently abundant. In the period following, the SILURIAN, the influence of the Mollusca is still paramount—hence, frequently designated the "age of mollusks"—but we have here in addition the first unequivocal evidences, in the shape of fish-spines, teeth, and armor-plates, of the existence of the higher backboned animals. Here, too, belong the earliest inhabitants of the land whose remains have come down to us, two scorpions and a possible cockroach, true air-breathers of the modern type. The coral animal, whose presence in the Cambrian deposits has not yet been demonstrated, seems to have found an unusually congenial home in the seas of this period. The DEVONIAN was pre-eminently the period or "age of fishes," a class represented by the two familiar types of sharks and dog-fishes (cartilaginous fishes) and ganoids, the last comprising forms like the modern sturgeon, in which the body was protected by an armor

of enamel plates or scales. The more highly constituted osseous or bony fishes had not yet been evolved. In the rocks of this period we find the earliest traces of animals that inhabited fresh water (fresh-water mussel), and the first of the air breathing mollusks, a land snail. A promising terrestrial vegetation had gradually been unfolding, which in the succeeding CARBONIFEROUS age attained to almost unparalleled luxuriance. The vast deposits of coal which have so long administered to the wants of man bear ample testimony to this enormous development. For the first time do we here meet with animal forms of a grade of organization higher than the fishes; giant animals of the salamander type sported in the existing carbonaceous marshes, inhaling an atmosphere supercharged with carbon, and giving forth to the solitudes not improbably the earliest organic sounds whose audibility was above that of the hum of insects. Hitherto, as far as the facts in the case have been revealed by geology, a general silence had pervaded the organic universe; the land, as well as the water, was tenanted by organisms to whom the production of sound was a stranger, and whose conception of the same, if such conception actually existed, must have been principally dependent upon the interaction of the inert mechanical forces alone. The PERMIAN period brings forth the earliest true reptilian forms, and we therein note a step in advance.

It is not until the succeeding, or TRIASSIC, period that we are presented with the first of that series of animals, the Mammalia, whose special development constitutes the most marked feature of the organic life of the present day. A lowly form, most nearly related to the marsupials, ushers in the class of the most highly organized of all animals. With this period a distinctively

new era dawns upon the horizon. The familiar types of the preceding periods, if they have not already completely died out, now rapidly decline; new forms take their place, and a more generally modern aspect is gradually being introduced. The mollusks are no longer in principal part brachiopods, but of the type of the snail and the clam; the old-time cuttle-fishes of the four-gilled order (represented in our own day by the Nautilus), although still flourishing, find their ultimate successors in the more highly organized two-gilled squid-like forms; the horseshoe- and ordinary crab, and their allies, have usurped the place of the trilobite among crustaceans; while among the lower orders, such as the sea-urchins and polyps, we find the true urchins taking the place of the more primitive stone-lily (crinoid), and the star coral that of the tabulate and rugose types. Progressive development is everywhere manifest; we proceed from low to high, from the more generalized to the more specialized. The distinction in the faunal aspect separating the Triassic from the Permian period is more marked than that separating any other two consecutive periods since the Cambrian; we recognize here a great "break," a seemingly new impetus having been given to the peopling of the earth. Such a break likewise separates the Cambrian and the Archæan periods. The JURASSIC deposits yield the earliest unequivocal traces of a feathered creation; reptilian in many of its characters, ornithic in others, the first of the feathered tribe with which we are acquainted is as well reptile as bird. Its contemporaries numbered many of the most bizarre forms whose records have been left to us—reptiles of the air, sea, and land, whose ponderous proportions are, in many cases, only matched by the whale, and whose avian affinities prove them to have been the

ancestral stock whence some of our modern birds have been derived. The monsters of this golden "age of reptiles" were largely continued into the succeeding CRETACEOUS period, when, however, they gradually succumbed, and ultimately, completely passed away. Their successors are the turtles, crocodiles, lizards, and serpents of the present day. This period is likewise marked by the advent of the osseous fishes, the type of fish structure which dominates the modern seas. Passing from the Cretaceous to the TERTIARY period, we note the most marked of the numerous organic changes that present themselves in the geological system. As if with one jump, the shadows of existing life are called upon the scene; modern type-structures everywhere prevail, even though generic or specific identity be a matter of later day. We recognize in the Tertiary fauna the type of the existing mammal, bird, reptile, amphibian and fish; the shells are essentially of the same character as those of our seas, and many of the forms are even specifically identical. And the same may be said of the star-fishes, sea-urchins, and polyps, down to the lowest order of animals known. Correlatively with the development of the modern fauna we remark the disappearance of those singular forms which served to distinguish the periods preceding—the salamandroids of the Carboniferous and Triassic periods, the Jurassic and Cretaceous bird-like reptiles, and the toothed-birds of the Cretaceous period. Finally, in the POST-PLIOCENE we are dealing with a faunal assemblage practically identical with that of the present day. Here man first steps in, ruler of the universe.

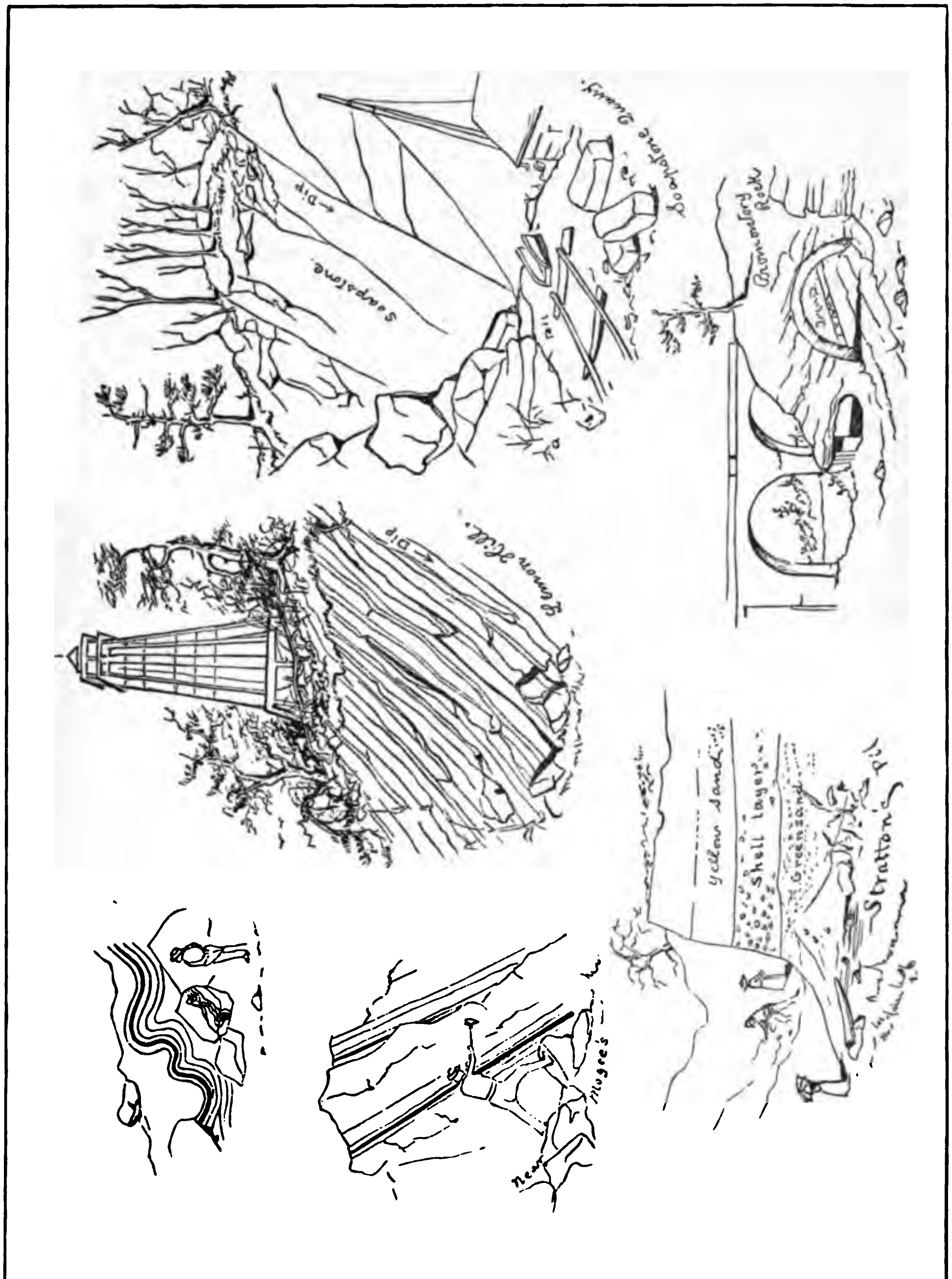
The periods or formations that we have been considering have been subdivided by geologists into minor periods or formations, depending upon certain special relationships or differences, but

these need not concern us here. They have also, and for similar reasons, been united into more comprehensive groups, defined by the big breaks that have already been indicated; but these, likewise, have no special interest for us at present. Let us for a moment turn our attention to the signification of a "break;" what is its meaning? Imagine yourself transported back to the Devonian period, and standing upon some fossiliferous deposit near the sea-shore, as, for example, the Silurian along the coast of Maine. What is happening about you? Everywhere around you observe distinct evidences of destruction; the streams of the land, and the billows of the Devonian sea are doing common work in readjusting the materials of the land-surface. A new deposit of sand and mud, the result of this general destruction, is forming immediately along, and a little outside of, the coast line, in which many forms of organic life, characteristic of the period to which they belong, will, doubtless, find a congenial home, or be buried pell-mell in a whole or fragmentary state. Under proper conditions these remains may ultimately become fossilized, and if the deposits happen to be elevated above water, serve as a geological land-mark to the future investigator. But while this is taking place outside of the coast-line, the case is quite different with the actual spot (Silurian) upon which you are standing. No such formation of a fossiliferous deposit is there taking place, and, indeed, as long as the locality remains above water no marine deposit can be laid down on top of it. It results from this, that while a Devonian deposit is accumulating in Massachusetts Bay the Silurian dry-land remains practically unchanged, except in so much as it may undergo disintegration and waste. Time rolls on, we may be entering the Carboniferous

and Permian periods, and yet through the persistent elevation above water of the Silurian land-surface the same undergoes no material alteration. The Silurian fossils still crop out everywhere, and we see nothing of newer date. Finally, let us conceive that in the Triassic period submergence of the land area takes place. The surface is covered with a new deposit, in which are harbored the remains of an entirely new series of organisms, organisms no longer of the Silurian type, but of that characteristic of the Triassic period. Conceive now the re-elevation of the ancient land area and its newly imposed deposit; what appearance would it present? A Silurian formation would be found in juxtaposition with one of Triassic date, a Silurian fauna wholly differing in its essential components, in juxtaposition with a Triassic one. We would have a true break presented, and one whose duration in time is the measure of the interval between the Silurian and Triassic periods—*i. e.*, the equivalent of the Devonian, Carboniferous and Permian periods. It is true that in the meantime a land-surface or fresh-water deposit may have been accumulating, but formations of this character are in general of comparatively insignificant extent, and do not in most instances materially affect the break.

A juxtaposition, such as we have above indicated, has actually taken place in some parts of the earth's surface, and, indeed, is perhaps nowhere better shown than in our own immediate neighborhood, at Port Kennedy, for example, where the vast masses of the Triassic red rock rest directly upon the blue Silurian limestone. The intermediate formations are here entirely wanting, and we have convincing proofs of a profound break. A break, whether large or small, is, therefore, evidence of a want of chronological continuity

in the geological series. Where the deposition of sediment has been taking place continuously from period to period—*i. e.*, in such localities where a steady subsidence has permitted the piling up through ages of deposit upon deposit, or where the laying dry of a land-surface was only a temporary incident—no breaks occur. The formations succeed each other serially, and the life-forms, instead of showing abrupt gaps in their chain, exhibit that progressive modification which leads them step by step from the faunal type of the early period to that of the period of later date.


Soapstone.
Dip
Soapstone Quarry
Lemon Hill.
Dip
Promontory Rocks
Yellow sand
Shell layers
Greensand
Stratton's pit

the rock surface. The mica forms a part, indeed a very large part, of the solid rock, and as such a constituent it enters either as the white variety, known as MUSCOVITE, or the black variety, BIOTITE. In technical phraseology the rock is "micaceous;" wherever it occurs, we meet with those glistening particles on the roadside to which reference has been made. The logical inference is that these scattered particles have been derived from the solid rock, which through some process or other has been compelled to yield up its constituent parts. Our deduction is proved to be a correct one, for everywhere where the rock is undergoing special decomposition or disintegration we notice an unusually large accumulation of mica scales.

But along with the mica particles we find on the roadside much greater quantities of something else. Pick up a handful of the substance you are walking upon, and examine it. You will find it largely composed of grains of sand (QUARTZ), which when separated and placed in the mouth produce a gritty feel about the teeth; placed in water they do not disturb its transparency, but quietly sink to the bottom without dissolving, just as the grains of sand of the seashore would do under similar conditions. Take your original handful, however, without removing any of its components, and place it in water, and you will have mud. This shows that it contains something else besides mica and sand—the body of clay. The substance of both clay and sand is contained in the rock masses that we have been studying, and which everywhere jut out from the soil. The sand is derived from the quartz of the parent rock, and the clay from the mineral known as FELDSPAR. So far, therefore, our soil, or mud, or dust, is the product of the decomposition of some solid rock mass, and this is not only the

case here, but also over a large part of the earth's surface. The red soil of New Jersey, familiar to all travelers on the railway connecting Trenton with Jersey City, clearly points to the decomposition of the underlying red sandstone; the white roadbeds of the Montgomery and Chester Valleys, which so readily form into a sticky paste after each rain, betray the existence of a foundation limestone; and, similarly, the heterogeneous assortment of clay, sand, and mica with which we have become acquainted point to the presence of some rock masses into whose composition these various particles enter as direct constituents. Now, what is the character of such a rock? Everybody is probably more or less familiar with the structure of granite; it is in principal part an aggregate of three mineral species, quartz, feldspar, and mica, which in their relations to each other affect no definite arrangement. Dismissing the mica, with which you are already familiar, let us briefly direct our attention to the two remaining minerals. Looking at a piece of coarse granite it will be observed that certain of its particles present to the eye a glassy or vitreous appearance, while others, again, present the appearance of pearl. Further, that the glassy particles break irregularly, whereas those having a pearly lustre show a decided tendency to break along pre-determined plane surfaces, "cleavage planes," which are in some way directly connected with the molecular structure of the mineral species. The glassy particles are the quartz (silicic acid), and the pearly ones the feldspar (silicate of alumina in principal part) of the rock. The quartz is usually of a grayish or bluish cast, whereas the feldspar may be of various colors—red, blue, green, gray or white—and is that element of the rock, which through its

own tint, imparts the particular coloring to a given block of granite.

Apply the blade of your knife to the quartz particles; you find that it produces no impression. Repeat the operation with the feldspar, and you will observe that through the exercise of considerable pressure an impression can be made. The relative hardness of the two minerals is thus determined, and the quartz is found to be considerably the harder of the two. If, again, we make the test by the minerals themselves, we will find that the quartz scratches feldspar, whereas feldspar will not scratch quartz. Mineralogists have found it convenient to establish a comparative scale of hardness covering all minerals, and they have placed at the two extremes talc (No. 1) and diamond (No. 10), the former representing the softest of all minerals, and the latter the hardest. Between these are, following in the order of their hardness, gypsum (2), calcite (3), fluorite (4), apatite (5), feldspar (6), quartz (7), topaz (8), and sapphire (9).

Examine now a fragment of rock such as crops out almost everywhere in the Park, or along the lower Wissahickon. You will in most cases readily recognize the elementary components of granite; the quartz, feldspar, and mica are all there, but possibly the grains, especially of the first two minerals, are very much smaller, and may for some time make it a little difficult to determine which is which. Indeed, in some places, one or other of the elements may be completely wanting, but still in a general way the rock can be said to have a granitic appearance. One important difference, however, can scarcely fail to strike even the least careful observer. Standing off at a little distance from the rock, and looking at it in the mass, there will be observed a peculiar paral-

lelism in its structure; a little closer investigation shows the banded or striped appearance to be due to a disposition in direct lines or layers of the different rock ingredients, the black lines or bands being the lines of mica scales, and the blue (or bluish) and white lines, the quartz and feldspar. This structure is perhaps nowhere better exhibited than along the Wissahickon bridle-path, a short distance beyond the newly-constructed Reading Railroad viaduct. Here the bands follow each other in beautiful succession, and in their numerous convolutions bear testimony to the great folding or crumpling which the rock masses have undergone. The rock before you is GNEISS, which, as already remarked, has the essential constitution of granite, but which differs in the foliated structure to which your attention has been directed. Closely scan the outcrops as you move up the bridle-path; every now and then it will be seen that there is a tendency on the part of the mica to preponderate over the other minerals. The scales become larger, and they pack closely, so that what is left between them (quartz) becomes of only secondary importance. The rock becomes more and more micaceous, until finally it assumes the structure designated by geologists MICA-SCHIST. Every gradation from a typical or true gneiss to a mica-schist, and from the schist back again to a gneiss, can everywhere be detected along the road. To these two kinds of rock, gneiss and mica-schist, must be traced the origin of the sand, dust, and mud, whose history we have been attempting to unravel. In the West Park, in the East Park, in the heart of the built-up portion of the city itself, where excavations have been made, as along the Pennsylvania Railroad immediately beyond the Schuylkill, at Merion, Bryn Mawr, and Haverford, along the Schuylkill as far as, and a little beyond Lafayette, at Germantown, Chest-

nut Hill, Wayne Junction, Jenkintown and Frankford, we on all sides meet with rocks belonging to one or other, or to both of these series, and with scarcely anything else. Every railroad cut, every excavation of any note, every outcrop of solid rock in the region comprised within or between the points indicated, shows gneiss or mica-schist. Geographically considered, for a distance of ten to twelve miles, or more, back of the Delaware River, and extending to a N. E. and S. W. line uniting West Trenton on the Delaware with points lying a little to the outside of Yardleyville, Jenkintown, Chestnut Hill, Lafayette, Bryn Mawr and Media, the region is one of gneisses and mica-schists. The rocks, which have a general northeast and southwest trend, or what in geological phraseology would be termed STRIKE, may differ locally in character, but, taken all in all, they present a pretty uniform structural appearance. In view of this general identity, and the absence of all evidence indicating that the rocks belonged to more than a single series, geologists have considered them in the light of a unit formation, the "Philadelphia" or "Schuylkill Gneisses and Mica-Schists." Nowhere in the entire tract covered by them has there ever been discovered even as much as a trace of a fossil, whether animal or vegetable.[1] Inasmuch, therefore, as the determination of a geological formation is effected almost wholly by the character of the contained fossil remains, we are in the present instance confronted with a difficulty which, in combination with other difficulties hereafter to be referred to, full thirty years of study and examination have failed to overcome. In other words, it is still at the present time impossible to say to which of the geological horizons the Philadelphia gneisses and schists belong—whether to the Archæan, as has been urged

by many, or to the Silurian, or possibly even the Devonian, as has been hypothecated by others.

Dropping the question of age for a moment, let us see what else of importance can be derived from the study of these crystalline rocks. Leaving the Fairmount Park boat-house, near the old reservoir, the traveler on the Schuylkill, with his eye well to the right, soon notices masses of rock cropping out of the hillside, showing the soil to be of comparatively insignificant thickness, and to be everywhere underlaid by hard rock material. At almost all the localities where the rocks come to the water's bank the beds or strata of which they are composed can be clearly seen to hold an inclined position, the declination, or DIP, being in the direction of up stream, or to the north, and at angle varying from 25 and 40 degrees to the vertical. The foot of Lemon Hill, immediately underneath the lookout, with its heavy beds dipping at an angle of 40°, beautifully exhibits this feature, as well as the minor eminences further along. Just before reaching Girard Avenue bridge the gneiss in many places becomes very coarse and granitic—indeed, passes off into true granite. The individual particles of quartz, feldspar, and mica are very prominent, and of the last more or less perfect six-sided crystals can be obtained in quantity.

In Promontory Rock, just beyond the bridge, we have a noble exposure of what might be considered typical gneiss, the foliation being finely exhibited. Here and there the foliæ show a tendency to become flexuous or wavy, a structure which can be advantageously studied on the river side of the tunnel, but still better in a small outcrop which occurs a short piece above hidden in the Catalpa bushes. On the high ground, along the line of the railroad, the rock bears testimony to having undergone rapid disinte-

gration, the white patches of decomposed or "kaolinized" feldspar indicating the character of the work that is being performed in nature's silent laboratory. Observe on the opposite side of the river the massive beds of gneiss, topped by a capping of red gravel and clay.

Immediately beyond Columbia Avenue bridge a prominent rock, some 25 or 30 feet high, stands out over the roadside, forming a marked feature in the landscape. The black color of the upper beds, which dip at a very moderate angle, is due to the unusually large quantities of black mica scales with which the rock is crowded, and in part to the presence of an accessory greenish-black mineral, HORNBLENDE, which superficially resembles the mica, but which can be distinguished from it by its glassy lustre, and the absence of a scaly structure. At Wissahickon, along the line of the horse-cars, and just outside of the grounds of the Riverside Mansion, there are a series of fine outcrops, the strata here being a more or less compact bluish gneiss (or where exposed to weathering, as the result of the oxidation of the contained iron, yellowish-brown or brown), alternating with bands of the more foliaceous mica schist. Opposite the Reading Railroad depot a long line of disintegrating gneiss is cut through. The same series of rocks underlie Manayunk (very micaceous here, and through profound disintegration, as seen on the hill-road, forming a heavy sand) and Roxborough, and other localities further to the north. The singularly picturesque outlines into which the surface of the country has been worn—the undulating knolls and receding hollows, so distinctive of this region—are exhibited to good advantage about Shawmont station. On the line of the newly constructed Schuylkill Railroad, about 100 paces this side of

the viaduct crossing in front of Prince's soapstone quarry—*i. e.*, a little more than a quarter-mile south of Lafayette station—the rocks on either side of the railroad will be seen to alternate very rapidly between gneiss and mica schist, bands of two, three, or more inches of the former separating the very much more perfectly developed lamellæ of the latter. Myriads of reddish-brown garnet crystals, ranging in size from small shot to a pea, occur imbedded in the mica schist at this point, appearing either directly on the surface of the mica, or immediately underneath it, thrusting up the same into countless nodular eminences. They are to be found also in considerable numbers in the wash-out at the base of the rocks.

Just before reaching the quarry above referred to, a very perceptible modification in the rock structure is noticeable; the layers of grayish- or greenish-white mica are replaced by layers of a much less flexible and dark-green mineral, known as CHLORITE (an impure silicate of magnesia and alumina), which here forms CHLORITIC-SCHIST or slate. The nature of this rock, which forms the south wall of the quarry, and which dips in, still toward the north, at a steep angle, can be observed to best advantage immediately alongside the small work-house erected in the pit. The inner face of the quarry, or that which runs parallel with the railroad, is made up in principal part of two more or less distinct kinds of rock, a white and a green, whose relations to each other are not everywhere clearly defined, but which in a general way maintain a nearly parallel course. The white rock, also of a light sea-green color, is TALC (STEATITE), a hydrous silicate of magnesia, very soft and crumbly, and having a decidedly greasy feel, as can be readily experienced by rubbing the fingers over the large blocks

that everywhere lie around. It is this substance, better known as soapstone, ground into powder, which is so extensively used by shoe-dealers to "grease" the interiors of their shoes. The brown, rust-like blotches which mark many of the smaller blocks, appearing as though nails had rusted away in the mass, are the result of the decomposition of a mineral common to these rocks, BREUNNERITE. The white rock is extensively used in the manufacture of fire-brick, as linings to iron furnaces, being but little affected by heat; a roof-cement is also prepared from it. The green rock adjoining the white, or lying enclosed within it, is a tougher variety of the same mineral species, differing but little either in its chemical or physical properties. Commercially it has but little value, being sparingly used for building purposes. Soapstone pencils are prepared from it, although not to any extent at this locality. Bundles of a white fibrous mineral, ASBESTOS, having superficially somewhat of the characters of talc, may be observed here and there occupying crevices in the steatite or chloritic slate.

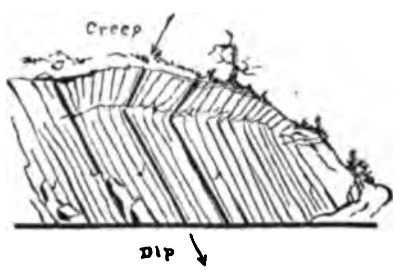
At the southeast corner of the quarry the line of demarkation between the talc and chloritic slate is well defined by a split running clear from the top to the bottom; on the opposite, or northern face, the boundary line is not so readily determined, being obscured by irregular masses of a tough greenish-black rock (which, when struck with a hammer, shows a snow-white spot) under which the soapstone passes. There has been much conjecture respecting the nature of this black-blotched SERPENTINE, but it must be confessed that our positive knowledge concerning it is still very limited. By some it is held to represent a volcanic intrusion, whose contact in a molten condition with the schists and gneisses has brought about

their modification into chloritic slate and soapstone. By others, on the other hand, the rock is looked upon as being merely an interbedded stratum, having no connection with any deep-seated forces. This latter view appears to be more nearly the correct one, inasmuch as at several points, as a short distance above Lafayette and at Rosemont, the rock appears clearly stratified with the soapstone.

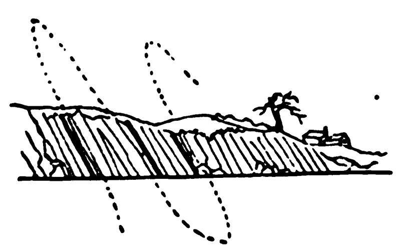
The exposure forming the north wall of the quarry is followed by a considerable thickness of the green chloritic slate, beyond which a second exposure of the nodular serpentine is indicated by a long line of scattered boulders running up the hill-slope through the woods. This same line of boulders can be traced, with interruptions, in an almost direct course northeastward to Chestnut Hill. It outcrops in masses along Thorpe's Lane, and forms in part the eminence at the crossing of that road over the Wissahickon. West of the Schuylkill Rose's quarry, directly opposite Prince's, marks the continuation of the serpentine belt, which can be traced thence to the neighborhood of Media, and beyond. Other more or less parallel belts of the same, or a closely related, rock lie to the north of it, furnishing in certain localities, as in Chester County, serviceable building stone. The "greenstone" fronts of the city, seen in such buildings as the Academy of Natural Sciences, the University, the Normal School, the Lutheran Church (Cor. Arch and Broad Streets), and in many rows of private residences, are serpentine.

Between our present position and Lafayette, somewhat less than one-quarter mile, the dip of the gneissose rocks continues nearly uniformly to the north, although just before reaching the station there is a slight reversion in the opposite direction—*i. e.*, south. Immediately beyond the station platform we again enter a cutting, and here the rock masses appear to lie in two distinct directions.

For the greater part of their height the beds stand vertically, on their edges; or, if we pass a little further into the cut, they show a decided inclination (dip) toward the south. The top portions of these same beds, singularly enough, decline in the opposite direction, or to the north. A hasty survey might, indeed, lead to the supposition that the strata actually inclined this way, but a little closer inspection will soon satisfy us that this is not the case. The beds



or strata are all fractured not very far from the top, and this, as well as the over-turn, is due to a downward pressure, caused by weight of material along the hill-slope of which the rocks form a part. This CREEP, as the structure is known to geologists, is of frequent occurrence among the Philadelphia rocks, particularly in localities where the rocks are thinly bedded. About 150 paces beyond Lafayette station a narrow band of white quartz might be seen to the right of the track running about half way to the top of the rocks, then suddenly doubling upon itself, descending to form a sharply-compressed inverted V. Although its exact relations cannot very well be



made out, it would appear as though it had been bent upon itself, and if this is so, the rock between which it is enclosed must partake of a similar configuration. Our suspicions are at once aroused, and we suspect that not only may folding have taken place in this one

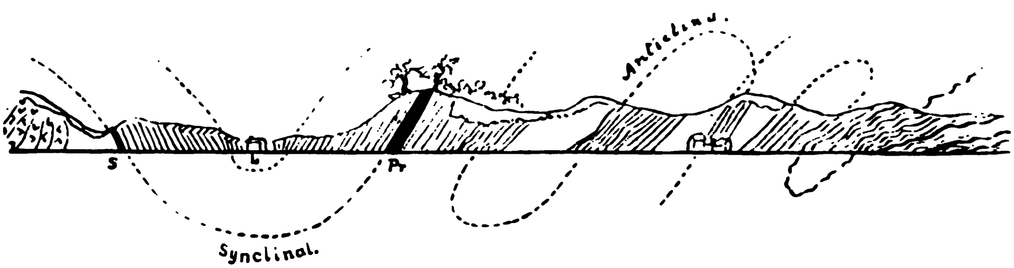
4

spot, but in others as well, and that, therefore, the rock mass, instead of being made up of so many distinct strata as we see them, may in reality consist of a very much more limited number, only appearing numerous through a process of sharp zigzag folding. We have discovered an important key to the solution of a most intricate problem in geological architecture, and one that cannot be too attentively studied.

At the first road crossing beyond the cut, where the surface has been worn to a generally low level, we observe to our right, some three or four minutes' walk up the wagon road, and on its south side, an outcrop of mica schist. Underlying, and dipping beneath the bottom layers of this rock, you will detect the now familiar serpentine, which here and there reappears on the surface. Continuing along the railroad, and when barely beyond the foot of the first hill, we perceive on the right a broad vein, several feet in thickness, of coarse white granite, which practically marks the beginning of a new formation. Beyond this point, and for a distance of about a mile and a half to the north, or to the limits of Spring Mill, the rocks acquire distinctively new features. The characteristic micaceous rocks disappear, and in their place we have rocks into whose composition the blackish mineral hornblende largely enters. The free quartz is in most places of a decidedly bluish cast, and this tint, in combination with the black of the hornblende, imparts to the mass a well-pronounced blue-black color. The granites, SYENITES, and gneisses of this region belong to the Laurentian series, and are considered to represent very nearly the oldest of the deposits developed in the United States, and not improbably they are of a date not very far removed from that of the most ancient deposits

with which we are anywhere acquainted. Special reference to these rocks will be made in the next chapter.

In the accompanying diagram we have represented graphically the *ensemble* of the geology such as we have studied it from the boat-house to the furthest point reached on our journey. Let us see what it indicates.



Section along the Schuylkill to beyond Lafayette (L).

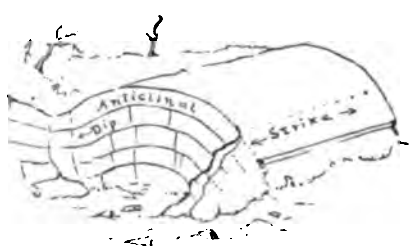
It has been found that from the boat-house to near Lafayette the rocks dip pretty uniformly in one direction—*i. e.*, to the north. Minor undulations tending to complicate the general structure may exist, but while in themselves apparently contradictory, they no-wise invalidate the system drawn from the more prominent folds. Just at Lafayette the system changes; the strata south of the station still dip to the north, whereas those on the north side of the station dip in the opposite direction. Now, inasmuch as the strata on both sides of the station are of practically the same character, and since we know (Chapter I), that inclined beds such as we see them here are in reality only parts or sections of folds whose arcs have been removed through aqueous denudation, or lie concealed beneath the earth's surface, we naturally conclude that the strata at this point form a basin-like fold, appearing on opposite

sides to form the boundaries of the trough. A fold of this kind is known to the geologist as a SYNCLINAL, one arching in the opposite way, or in the form of a dome, an ANTICLINAL. How much of the rocks lying to the south of Lafayette form part of a single large fold, or to what extent the present structure may be due to a series of compressed anticlinal and synclinal folds, it is difficult, or even impossible, to state, owing to the very intricate manner in which the rocks appear interwoven, and the sudden alterations which mark their surface aspect. But we have seen, as in the case of the quartz vein, how a sharp fold can be made, and yet the two opposite sides of the fold be practically parallel to each other.

Three positive conclusions can be deduced from the premises laid down in our diagram. 1. That the Philadelphia gneisses and mica schists have undergone considerable crumpling and folding—a process, doubtless, due to a settling of the earth's crust; 2. That the rocks of this series are of newer date than the granites and syenites lying to the north, inasmuch as they can be seen from the inclination of the strata to have at one time overlaid them; and 3. That the surface of the country was in former periods very much more elevated than it is at the present day, the higher elevations not impossibly rising two, three, or more miles into the air. Throughout the entire area occupied by these gneisses and mica-schists the same general structural features are maintained; the rocks everywhere show signs of great disturbance; the dip is more or less uniformly toward the north, except along the northern boundary, or on the line of contact with the more ancient Laurentian rocks, where it is reversed in the direction of south.

The outcrops of gneisses and mica-schists along the Wissahickon do not differ essentially from those on the Schuylkill, although they

exhibit in a very much more marked degree the numerous folds and convolutions into which the strata have been twisted. This structure, as has already been stated, can be seen to best advantage on the bridle-path, a short distance beyond the Reading Railroad viaduct. At about a point opposite the first ferry, black crystals of an accessory mineral, HORNBLENDE, some half inch or more in length, will be found imbedded in the rock, giving it a "hornblendic" character. Crossing by the second bridge, and following the road straight ahead, instead of turning by the covered bridge, we soon come to Rittenhouse Town, where a large dug-out, McKinney's quarry, finely exhibits the anticlinal structure in the

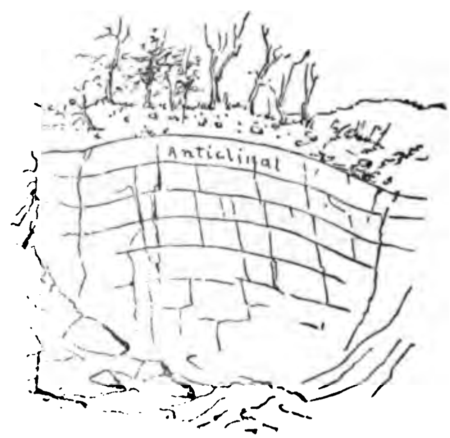


blue gneiss. The curved lines in the back wall of the quarry show that the centre of the excavation is practically under the highest point of the arch, or in the centre of the anticlinal. The "roll" is a very gentle one, and, therefore, the dip on either side is only quite moderate. In order to fully comprehend the structure at this point, you have but to picture to yourself a longitudinal half of a jelly-roll sliced transversely, and that you are looking at the cut end. The trend of the cake is here away from you, and so in the rocks, the trend or STRIKE is in the same direction. The wall of rock on either side is only the remains of an arch which formerly extended, or domed over the space that is now quarried.

Specimens of the glossy black mineral TOURMALINE are sufficiently abundant at this locality, as also blue-green APATITE (phos-

phate of lime), implanted in feldspar, and rose-colored CALCITE (carbonate of lime). The mineral STILBITE likewise occurs, coating the surface of the gneiss in many places with rosette-shaped clusters of a dirty-brown crystal. Much of the rock at this place has the surface ornamented with a beautiful fern-like tracery—"dendritic markings"—which is commonly taken to represent moss impressions, but which in reality is only an iron deposit, here of various colors.

A short distance up the road, toward Main Street, Germantown, you will observe the rocks on either side to have undergone profound disintegration, the whole mass literally crumbling to powder; the same condition is beautifully exhibited in nearly all the cuts in this region, and may be studied to advantage along the line of the railways, where it betrays in a most instructive manner the method of the formation of soils. An exposure of this kind is seen on the new Pennsylvania Railroad at the first bridge-crossing above Chelten Avenue; above Carpenter station the disintegration of the gneiss has resulted in splitting the rock into a series of closely-packed vertical laminæ, which may be separated by the blade of a knife like so many plates of mica. At Walnut Lane station, on the Reading Road, despite the complete decay, the position of



Anticlinal Arch, McKinney's Quarry.

the beds has been but barely disturbed, so that the character of the rock is almost as well indicated as though it were in its normal solid condition. But probably the finest example of decomposed gneiss to be seen in the vicinity of Philadelphia is that occurring near Gray's Ferry, where the beds of white kaoline form a marked feature in the rock physiognomy.

Beyond Rittenhouse Street ("Artists' Corner"), to opposite Chestnut Hill, the rock-masses along the Wissahickon exhibit no special characters by which to distinguish them from the similar rocks of the Schuylkill. Beds of gneiss of greater or less thickness alternate with micaceous slates or schists, largely garnetiferous, which, excepting local irregularities, dip uniformly toward the north up to a short piece this side of Thorpe's Lane, where the dip is suddenly reversed, repeating the structure which we had occasion to notice as characterizing the northern boundary of the Philadelphia gneiss region. At this point a mass of serpentine, a continuation of the Lafayette belt, crops out across the road, and can be followed along the lane in a series of boulders to the heights of Chestnut Hill.

About a quarter-mile beyond the serpentine outcrop, opposite to where a house faces the nearly vertical strata, the remains of a neglected, and in a great part overgrown, granite quarry, which has furnished the building material for the convent on the heights near by, extend into the hill-side. Note here the altered character of the rock, and observe the sudden alternation of the granite and gneiss on the south wall. A short piece further up the road, where, in emerging from the White Marsh valley, the Wissahickon makes a sharp rectangular bend, the character of the

rock once more changes, and we are brought face to face with the unmistakable hornblendic masses of the Laurentian SYENITE. We have followed the Wissahickon to the open country, and have there reached the boundaries of the gneiss region.

The readily accessible localities for gneiss outcrops are very numerous throughout the region on both sides of the Schuylkill, and everywhere the rocks present approximately the same general features. Here and there, an alternation of black hornblendic strata, as seen at Columbia Bridge, about three-quarters of a mile further to the north, at the Falls of the Schuylkill, and in parts of West Philadelphia, imparts a little variety to the sameness of the formation, relieving the monotony of the interlocking gray or blue gneisses and mica-schists, mica-schists and gneisses. The same may be said of the coarse granites, a good example of which can be seen immediately at the Callowhill Street entrance to the Park, into which, as broad veins, the gneiss occasionally graduates. Almost everywhere along the north border where the formation abuts against the Laurentian it is "brushed" up, so as to rest upon the slopes of the latter, proving it to be of younger date. This feature of the reversed dip we have already examined above Lafayette and along the Wissahickon, but can with advantage refer to again in the two quarries which at Jenkintown station (Beechwood) lie on either side of the railway. The steeply dipping garnetiferous rocks, traversed by a broad vein of coarse, semi-graphic granite, are here beautifully exhibited. The southerly dip may be observed, too, along the open highways, where the edges of the strata come to the surface, as on the roads of Bryn Mawr.

Gneiss rock, unless it be of the compact variety seen at the

Rittenhouse Street quarry, can scarcely be considered to be a first-class building-stone, owing to the facility with which it undergoes decomposition; yet, for reason of a certain durability, and the readiness with which it can be obtained in the neighborhood, it is extensively employed for architectural purposes, entering largely as the foundation blocks in buildings, or as the undressed walls of suburban residences. To its facile disintegration in parts, and its capacity for resistance in others, we owe those delightful alternations of hill and dale which lend such a charm to the landscape about Wistar, Germantown, and Chestnut Hill.

IV.

OUR OLDEST PATCH OF LAND.

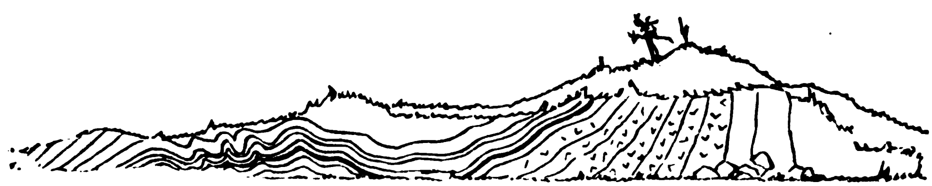
North of the line of the Philadelphia schists and gneisses, and extending from Trenton on the Delaware to West Chester and beyond, there runs a comparatively narrow belt of rock bearing in many points of structure a striking resemblance to the rocks which we have just been studying, but which, again, in many respects departs widely from them. The granites, syenites, and gneisses of this region, usually classed with the Laurentian series, are the oldest rocks of the neighborhood of Philadelphia, and represent practically the foundation rock of the continent. Throughout the greater part of their extent they define a prominent ridge, readily distinguishable in places as forming the southern boundary of the limestone valley lying to the north. The toughness of the rock and its resistance to erosion have combined to preserve it for a much greater length of time than the limestone, which, though of much newer date, yielding readily to the solvent action of water, has been reduced to a comparatively low level. We say that the limestone has

"weathered low," whereas the Laurentian rocks have "weathered high;" and it is this comparative weathering, depending upon the relative resisting powers of the rock-masses, which so manifestly controls the physiognomic aspects of the landscape. Were it not that some rocks yield more readily to the disintegrating influences than others, the landscape would be devoid of those manifold charms which are lent to it by the sudden alternations of hill and dale, mountain and valley.

A fine exposure of the Laurentian rocks is had on the new Schuylkill Railroad, beginning about one-half mile north of Lafayette station, and extending to Spring Mill. After passing the first road crossing beyond Lafayette, which approximately marks the boundary between the older and newer formations, the railway skirts the base of a hill along whose slope the rocks are well exposed. Almost immediately beyond the broad band of white granite which meets the eye on the right, we enter a region of blue or blackish rocks, whose peculiar color is due to the prevailing (bluish) tint of the quartz and to numerous dark-colored crystals or grains of hornblende. We note here, in fact, that the mica scales of the Philadelphia series of rocks have in large part been replaced by hornblende; and further, that the rock-masses have pretty much lost that foliated structure distinctive of typical gneiss and mica-schist, and that they are in a general way more decidedly granitic in appearance. They are the rock commonly designated SYENITE, differing from granite in the substitution of hornblende for mica, and from gneiss in the absence of the foliated structure. But insensible gradational shades unite the one with the other, as can be seen by the boulders lying on the left of the road, where in some

cases the hornblende has completely disappeared, leaving the rock a coarse grained granite, composed of quartz and flesh-colored feldspar; and, again, where this same granite shows a tendency to foliation, passing off into gneiss.

Under what appears to be the highest point of the hill the beds lie nearly vertically, although it is not a little difficult from the nature of the exposure to determine just exactly what positions they do occupy. At about the point where the strata first show a decided declination toward the north the rocks assume what might be considered to be the typical Laurentian facies; fresh fractures clearly



The Laurentian Exposure on the East Bank of the Schuylkill.

exhibit the distinctive blue quartz and an abundance of the black hornblende crystals. Old surfaces, on the other hand, are largely yellowish or brownish, due to the oxidation of the contained iron. Passing northward the inclination of the strata becomes less and less pronounced; through a series of gentle undulations they gradually assume the horizontal position, until, about 300 yards this side of Spring Mill station, they suddenly become highly plicated and contorted, recalling in their convolutions and general appearance the gneisses along the Wissahickon. Two or three rolls of rock, sharply defined by the curves of plication, stand out in promi-

nent relief from the wall of which they form a part. From this point to Spring Mill, where the formation disappears, the dip is uniformly to the north.

The Laurentian rocks may be traced eastward from Spring Mill by following the line of the ridge a little below the crest, which is formed by the gneisses of the Philadelphia series. Over a considerable extent, however, their determination is made difficult or impossible from the scarcity of outcrops, and from the circumstance that in many places they are overlaid by the sandstones of a newer formation, the Cambrian, lying on the north flank. On the heights between Lafayette and Matawna and Barren Hill the nature of the underlying rock is indicated by the hornblendic boulders which everywhere lie scattered about, and by occasional outcrops of the rock itself. An outcrop of the blue beds occurs on the right bank of the Wissahickon, just where that stream enters the hilly country from the White Marsh Valley, not far above the last bridge which carries the road over to Chestnut Hill, and just beyond the now largely overgrown granite quarry.

Forming part of the northern declivity of Chestnut Hill, where, however, the formation is almost entirely hid from view beneath the capping of soil, the Laurentian reappears to the east as a rather prominent ridge flanking Edge Hill on the south. Passing north from Jenkintown, on the Abington road, the traveler soon leaves the Philadelphia gneisses behind him, and mounting by easy stages a long eastwardly trending hill finds himself in the midst of rocks where decomposition has made severe havoc, but where certain characters still betray the relationship with the Laurentian series. Opposite Mooretown the strata stand on their edges, inclining

slightly toward the south; the character of the gneiss has here so far changed through decomposition as to render it difficult at first sight to determine to just which of a particular group of rocks it may belong. But the more compact boulders that here and there lie scattered over the road on to Abington, and to the heights of Hillside, with their masses of blue quartz and dark crystals of hornblende, leave no room for doubt in the matter, and clearly point to the rocks which we recognized on the Schuylkill as Laurentian to be their nearest of kin.

Looking up the long straight road which leads off to the left from Abington crossing, with the rays of the sun falling on the line of heights which shuts in the landscape in this direction, the observer will not fail to notice a sudden alternation in the character of the road-bed ahead. The distant white, contrasting sharply with the more sombre gray of the foreground, indicates the existence of a new formation. The rocks there are no longer gneisses or syenites, but sandstones (Cambrian), whose light color gives the peculiar white which is so eminently marked out against the mass of sky and foliage. Thus, by the character of the soil alone, we frequently determine the bounding line of a formation.

The gentle swell of country eastward, picturesquely dotted with villages and country residences, marks the outline of the same resisting gneisses and syenites in their trend (strike) to the Delaware River. The hard rock everywhere asserts its supremacy over the rock of weaker constitution, standing out prominently where the latter has been washed away. Landscape conforms to physical laws, and is thus made a powerful instrument in the hands of the geologist.[4]

West of the Schuylkill the Laurentian area steadily widens, and overspreads a large part of Delaware and Chester Counties; in its general aspect it presents the same features as the region to the east, and therefore requires no special consideration. The prominent wooded ridge, whose reflection is cast into the river opposite Spring Mill, and whose noble outline seems worthy of a more picturesque foreground than is constituted by the red roofs and black chimneys of busy Conshohocken, marks the passage of the belt across the Schuylkill.

The Laurentian being the basement or foundation rock of the region about—*i. e.*, the oldest—we would naturally look for its fragments in rocks of newer date, or such as must have derived their materials primarily from the destruction of this series. All mechanically formed rocks, whether they be gneisses, schists, shales, clays, or sandstones, are built up from the materials of previously existing rock-masses, and must hence contain in their own substance the substance of the parental rock, or that from which they were born. And where no special alteration has taken place the derivative ingredients of the one can frequently be traced to the other. It would be difficult, if not impossible, to prove from lithological considerations alone that the materials of the Philadelphia gneisses and mica-schists have been derived from the somewhat similar rocks of the Laurentian series, inasmuch as the former have evidently suffered to such an extent from metamorphism as to leave it doubtful whether the rocks as we now see them are in any way like what they were when originally deposited. But in the formation next succeeding the Laurentian, the Cambrian, where in many parts no metamorphic action has retroacted upon the rock structure,

distinct evidences of derivation and transference of material are strikingly manifest. These will be considered in the next section.

As far as we know no unequivocal traces of organic life have ever been discovered in deposits of Laurentian age; that life *did* exist at this early period, however, there can be no reasonable doubt, seeing how abundant are the animal forms that suddenly appear in the Cambrian deposits.[5] This conclusion is further sustained by the presence of large deposits of limestone and graphite, both of which probably represent organic structures.

V.

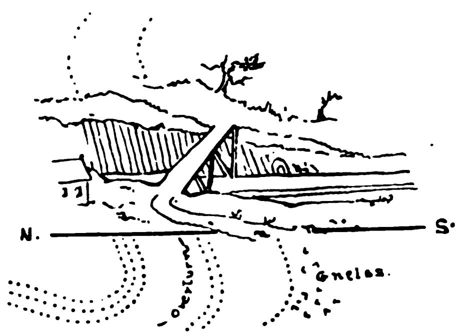
THE FIRST-KNOWN BEACH: A CHAPTER FROM CAMBRIAN HISTORY.

Passing off from the Reading Railroad depot in Chestnut Hill to the right we descend the slope of the Philadelphia schists and gneisses, and soon come to the toll-gate guarding the Flourtown pike; a little way beyond this toll-gate, as seen on the Bethlehem pike, a peculiar yellowish-white rock, in some places tough like flint, and appearing pink or pinkish on the translucent edges, and in others, scaly and decidedly friable, makes its appearance. This is the last rock to be seen on the hill-side, and dipping northward, or in the direction of the valley beyond, soon disappears beneath the limestone rock which forms the floor of that valley. The rock in question is quite distinct from anything that we have thus far studied. Thinly bedded, it breaks readily into flat-faced surfaces, and almost everywhere where it occurs even-shaped fragments may be seen scattered about over the road. The tough or more concrete layers are QUARTZITE, or quartz rock—*i. e.*, a rock composed wholly, or nearly so, of the mineral quartz—originally a sandstone, but in

which a fusion of the sand (quartz) particles into a compact mass has subsequently taken place. The more friable layers are what might be appropriately termed "earthy sandstones," containing an abundance of minute sand particles, bound together by an earthy base, in which numerous particles of white mica, or of a mineral allied to it, are imbedded.

The same rock, with but slight modification of structure, extends hence westward to Spring Mill on the Schuylkill, beyond which point it has not been traced. All along this line it forms the south boundary of the limestone valley, and where it has sufficiently resisted disintegration stands out as a prominent ridge or elevation; in other places it has crumbled low, and can only with difficulty be made out. Barren Hill, whose slope commands an extended view over the surrounding landscape, is built up of this rock, known here as the "Barren Hill slate," and similarly, the nearly equal eminence, its continuation, upon which the new St. Joseph's Academy (Convent) is situated. On the Flourtown pike, a short distance beyond the intersection of the Flourtown and Barren Hill roads (marked by a sign-post), and, therefore, but a little way beyond the convent itself, an outcrop of this rock appears on the left, forming the low bank of the roadside. Just beyond the crest of the hill we meet with a larger bank, where the strata, dipping away from us, or downward in the direction of the valley, are very much more clearly defined. Near the surface the rocks are badly broken through the weight of the hill-slope, and we have a repetition of the structure already described at Lafayette under the name of "creep." Continuing on this road, we soon reach the base of the hill, where the sandrock disappears beneath the limestones and clays of the valley.

East of our starting point just below the Chestnut Hill toll-gate the same rock continues uninterruptedly, and in a nearly direct course, to Willow Grove, a distance of some six miles. It forms a prominent ridge most of this way, and being the substance of Edge Hill, has received the local designation of "Edge Hill rock." To geologists, however, it is better known as the Cambrian sandstone, representing the oldest of the fossiliferous deposits developed in this country. In the deep cut at Edge Hill the rock is exposed for a length of several hundred feet, standing in thick beds almost

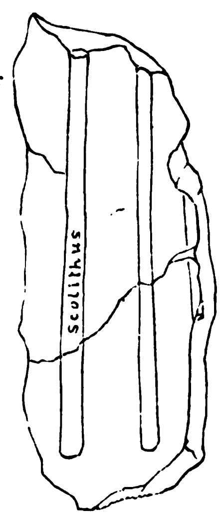


vertically on its edges; the slight dip indicated toward the south, or in the direction of the Laurentian axis (appearing as though the rocks passed *under* the older formation), is evidently the expression of an overthrow. In the quarry located in the town immediately east of the railway we have one of the most beautiful exhibitions of creep-structure to be found in the vicinity of Philadelphia.

How, you may ask, do we determine that the formation in question belongs to the Cambrian period? We have broken off fragment after fragment of the rock, and have thus far failed to discover in it any traces of fossils; and without fossils of one kind or another it is practically impossible to determine the age of a deposit. It is true, as we have seen by tracing the syenite beds beneath the sandrock, that the latter is of newer date than the former; and similarly, by tracing the sandrock beneath the valley

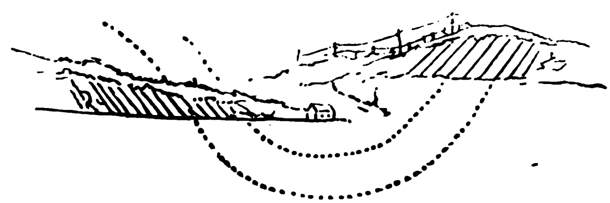
limestone, that the former is older than the latter. But this result gives us only a *relative* age, and does not of itself indicate *absolute* age.

Fortunately for the geologist, however, these same rocks, despite the fact that we may not have found anything, do contain in places something that materially helps to identify the formation. This something, which is of the nature of an elongated cylindrical body, some four to six inches in length, and of about one-half the thickness of a slate-pencil—indeed, in appearance very much resembling a pencil of the color of the rock in which it is imbedded—is supposed to represent the "filling" or core of a worm-burrow. These burrow-cores frequently lie closely packed one alongside the other, invariably parallel (or nearly so) to each other, and just as invariably at right-angles to the planes of bedding. Imagine a mud- or sand-beach burrowed vertically by worms, and the burrows on the death of the worms to be filled in with mud or sand, forming cores, and you will have precisely the structure which is found in these rocks. This most ancient representative of Pennsylvania's fauna, the *Scolithus linearis* ("linear worm-stone"), is the one solitary fossil occurring in this formation in the region about. Wherever it occurs, it occurs in this same rock, and where, as in the State of New York, it is associated with a host of other fossils, these fossils are of the character distinctive of the rocks to which the name Cambrian was first applied. Hence, we know that our formation is the Cambrian. See if we can find some of these fossils ourselves.



The North Penn. or Bound Brook Railroad from Ninth and Green Streets station deposits us at Beechwood (Jenkintown station); turning hence to the right we soon reach Jenkintown hamlet, where we meet the cross-road leading north to Abington. Following this road we almost immediately leave the characteristic gneisses and mica-schists of the Philadelphia series behind us, and just beyond the railroad crossing begin gently mounting the Laurentian belt. Here is Mooretown, and on the left of the road the outcrop of disintegrated rock to which reference was made when treating of the Laurentian formation. Passing Abington and proceeding some ten minutes beyond, the character of the rock suddenly changes. We have now reached the crest of Edge Hill, and the rock is the "Edge Hill rock," or Cambrian sandstone. It occurs here in thinly bedded disintegrated masses, crumbling readily, but some of the layers are very much firmer than others, and on the whole the deposit is not unlike that which crops out at Convent. Note that the strata, which are very steeply inclined, dip here to the north; they lie closely packed to the Laurentian, upon which they rest as the rock of newer formation. Descending the hill we sight on the left Rubicam station (on the East Penn. Railroad), whither we proceed for the purpose of examining the exposure of rock along the line of the railroad cutting. Following the track in the direction of the bridge ahead we enter a cut, the walls of which are made up of alternations of a micaceous slaty rock, in some places showing a greasy or plumbago-like surface, and the rock which we had just left on the top of Edge Hill, and there recognized as the Cambrian. We conclude, therefore, that the whole series is a unit, and that some particular condition attending or following the original deposition of sediment had

brought about the singular alternation of slaty and sandstone structure. Observe here that the dip of the beds is toward the south, or in the direction of the Hill, so that if the beds of the two localities are continuous one with the other, there must be a basin-like fold, or synclinal, between the two localities. And this is precisely the relation of the country.



Returning to the Abington road, and continuing our journey northward, we observe for a considerable distance along the road banks of rock fragments, which are used for macadamizing. Look over the pile carefully, and you are almost sure to find parts of, if not the whole, *Scolithus*, some very thin, others much more robust, but in either case clearly made out by their straight cylindrical outlines. Many of the rock fragments contain several such burrow impressions, and where this is the case you will note that they follow a course distinctly parallel to each other. We have thus the age of the rock formation about us established. About one mile from Rubicam station the road enters Willow Grove, a small hamlet and summer resort, which boasts of certain mineral qualities in its neighboring waters. The mineral spring house stands a little piece north of the railway station, to the left of the track. We follow a parallel road on the opposite side, and presently reach a village school-house planted at the entrance to a rugged patch of sloping woodland. We continue on

the main road, passing this village school, leave unnoticed a rocky wood-road that a little distance beyond leads off diagonally to the right, and turn (to the right) at the junction with the first direct road or lane. All along this road blocks of Cambrian rock lie scattered about, and the road-bed itself is decidedly sandy, the result of the disintegration, and the pounding up into minute particles, of the sandrock, or sandstone. Observe, as you pass along, that the ingredients of the larger blocks of stone get coarser and coarser; at first, the particles are quite fine, and make up a fine-grained rock; later they become coarser, like millet-seed, and the rock is a GRIT; and finally, the blocks are seen to be made up of distinct pebbles—pebbles of blue quartz—and they constitute CONGLOMERATE.

Arriving at the top of the hill we pass a farm-house on the left, and continuing through the straight lane ahead turn sharply to the left where it enters the woodland. Descending through the bush the road forks after a few minutes; we leave the main track, and striking to the right, by following an ill-defined path irregularly strewn with large boulders, soon reach the very picturesque locality known as The Rocks. Large blocks of a coarse conglomerate here lie scattered about in wild confusion, bearing testimony to the silent but steady work of destruction that is being performed in nature's laboratory. Above, more powerful masses, sharply contrasting in their rugged contours with the delicate tracery of the surrounding foliage, stand out in prominent relief from the hill-slope.

Interesting and picturesque as the scene may be to the artistic eye, the more interesting and impressive does it become when we arrive at a full comprehension of its inner meaning. Attention has already been called to the fact that the disposition of sediment

in the oceanic mass is such that a gradational assortment of its material invariably results: the finer particles are removed furthest out to sea, those less fine to a correspondingly shorter distance, and those of a coarse nature, dropped near shore. A pebbly or "shingle" deposit always hugs the coast-line; therefore, wherever in the ancient rocks we meet with extensive pebbly deposits—conglomerates or "pudding-stones"—we have in these deposits the testimony of ancient coast-lines or beaches. Here, at The Rocks, we stand upon the primeval Cambrian beach—the earliest formed beach of which any record has been left to us—and ponder over the countless ages that must have elapsed since it marked the borders of a vast westerly trending sea. The mind wanders back hundreds of thousands, nay, millions of years, and pictures to itself a bleak land-surface, mostly, if not entirely, devoid of a land vegetation, and harboring neither beast nor fowl; an atmosphere hot and moist, and charged with a measure of carbon that would have given but meagre chances for life to air-breathing animals of the kind living at the present day; a sea of high temperature, in which numerous bizarre forms of life, and again, forms but barely distinguishable from such as still disport in our existing waters, frolicked and battled in the already existing struggle for existence. With all the differences between past and present, we find that nature's laws, and their operations, were the same then as now. The sea beat upon the shore as it still beats; the rock-masses fell and broke as they still fall and break; and the same formation of a pebbly beach took place then as now. From the testimony of fossil rain-drops we know that the rain fell as it now falls, and the numerous sun cracks found in some localities prove that the mud dried and cracked under the influence of the sun's rays just as it dries and cracks at

the present time. It is, indeed, a vast contemplation, and one that cannot fail to appeal even to the least imaginative mind. No historical monument tells the tale that this one does; none that in any way comparable brings to the mind the sense of the real and the unalterable.

Whence came the pebbles that form the conglomerate? The blue quartz of the Laurentian gneiss gives us the clue. The Cambrian formation rests immediately on top of the Laurentian rocks, and from the destruction of these last has it obtained the materials of its composition. Pass over to the further side of the rocks, and you will observe that they dip steeply toward the hill-side, or to the south; the free edges now rising into the air were at one time united to an arch that completely lapped over the valley below us, and extended far beyond.

Continuing on the main road, which was originally left at the base of the hill, we almost immediately pass beyond the limits of the Cambrian area, and for about one-half mile or so before reaching Morgan's Mills again travel over the older crystalline rocks. Boulders of Laurentian gneiss or syenite lie scattered on either side of the road. In the railway cut to the left, just before entering the hamlet, you will observe that the wall of rock is of a purplish-red color, and quite distinct from anything that we have thus far seen. We here become acquainted with an entirely new formation. From this point for a distance of about thirty miles across the country, and extending in a continuous, but somewhat deflected, belt completely across the southeastern corner of the State, and into Maryland and New Jersey, the TRIASSIC red shales and sandstone everywhere occupy the country. Where the solid rock itself does not come to the surface we can infer its presence from the nature

of the soil—the red that appears in the farms, the red of the road-bed, and the red of the bank along which some tortuous stream may have wound its way.

Watch carefully the road upon which you walk. When opposite the entrance to the first house on the left, note the large pebbles that suddenly appear. We have evidently struck a second beach-line—the beach of the Triassic waters. Detach one of the larger pebbles if possible, or this can be done more conveniently from the bank inside the fence, and it will be seen that there are pebbles within the pebbles; in other words, your primary pebble is made from a rock which is of itself pebbly—a conglomerate. We have little difficulty in finding the source of this new material; we clearly recognize the Cambrian pebbles, and if the Cambrian formation now no longer extends quite up to the point where we are standing, we know that in former periods it did so extend. Commingled with these ancient pebbles are fragments of syenite, which prove that the materials of the Trias are at this point derived from the destruction of at least two formations—the Cambrian and the Laurentian. About a half-mile beyond the Mills, straight out on the main road, heavy beds of the "red sandstone" (here more of a grayish color) crop out on either side, forming by their exposed edge a nearly vertical wall. Looking at the parallel lines which mark the boundaries of the different beds or strata it would at first sight appear as though the beds were horizontally disposed one on top of the other, and that there had been no disturbance of any moment since the period of their original deposition. We soon discover that this view of the condition of things is not the right one, however, for when fully abreast of the rocks it will be observed that the beds are not only not horizontal, but that they dip at a moderately steep angle.

This is best seen on the side of the rock situated on the right of the road, where the dip can be clearly made out shearing diagonally across the road, or in the direction of north. The vertical face with the parallel lines is the *strike* of the rock, or the line in the direction of which the beds were laid down. Conceive the elevation of the land surface along this line and you will have that inclined position of the strata which has just been noticed. Everywhere in the Triassic area above referred to, or at any rate within the region about Philadelphia, the dip of the rock is uniformly in the same direction, toward the north or northwest Before leaving this spot observe how the consistency of the different layers varies; in some the rock is a coarse conglomerate, in others it is a fine-grained sandstone, and again, in still others it is an earthy deposit, with but little sand, and in the nature of a SHALE. These different structures indicate so many distinct conditions of deposition, from shallow to deep water.

The Cambrian sandstone which we have traced as the south barrier of the limestone valley from near Spring Mill on the Schuylkill to Willow Grove, and whose termination is reached just beyond The Rocks, is continuous with a similar belt extending along the north face of the valley. Here the dip is for the most part to the south, or in the direction contrary to that which obtains along the southern flank. Inasmuch, therefore, as the rock on both sides dips beneath the limestone, it would appear that the last was laid down in a synclinal trough, whose floor is the Cambrian sandstone. That this is at least in part the structure of the valley there can be no doubt, since borings made near its eastern termination have brought out from moderate depths beneath the limestone surface fragments of the older sandstone rock. The junction between

the northern and southern belts of sandstone is effected just west of Rubicam, where the included limestone, forming the head of the valley, thins off to a boat-shaped termination.[6] Westward, the northern belt is continued beyond the Schuylkill.

On the heights of Bridgeport, opposite Norristown, the sandstone, which is exposed in two pits in the chestnut-wood, is an exceedingly tough rock, largely red or reddish in color, and heavily bedded; it dips steeply in the direction of, and under, the limestone valley to the south. Further to the northwest, along the charmingly idyllic vale of Valley Forge, so fertile in its recollections of American history, and so little suggestive of the antiquity with which geology invests it, the rocks are more nearly of the character observed along the south side of the valley. The amphitheatre of wooded slopes, cut down through ages by Valley Creek and its tributaries, ancient and modern, is a legacy bequeathed to us from Cambrian times.

VI.

WHITE MARBLE STEPS AND WINDOW-FACINGS: A CHAPTER FROM "SILURIA."

One of the most striking features in the architecture of the "City of Brotherly Love" are the white marble window-facings and door-steps. They occur everywhere, and are everywhere looked upon in the light of an eye-sore by the stranger to the city. He passes by them and remarks only their monotonous appearance, or how clean or dirty they may be, the same that he does for the long line of red brick, and little reflects what wonderful history is written in their substance. Cursorily examined there is very little inviting in the stone; it looks in a general way like every other stone or rock, it feels and weighs very much the same, and altogether there would seem to be nothing special to arrest our attention. But all the same, there *is* a vast difference between it and most other rocks.

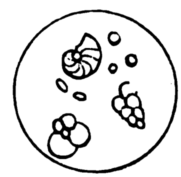
If we take a chip of such marble and drop it into a vial containing one of the stronger acids, as nitric or sulphuric acids, for example, it will be observed that almost immediately a peculiar

boiling or "effervescence" in the acid takes place, and that there is a simultaneous wasting away of our chip. The effervescence is due to the elimination by the marble of innumerable tiny bubbles of gas, which when collected and analyzed proves to be carbonic acid, the same that produces the familiar ebullition in soda-water. Evidently the marble has parted with some portion of its substance, but its final disappearance has not all been brought about in this manner, for we know that marble is more than simple gas. The rest of it has been taken up by the acid, and held there in solution, just as salt, dipped into water, is held by it in solution. But how do we determine what the residual substance may be? The process is a very simple one. Take another chip of marble, and subject it by means of a mouth blow-pipe to a degree of heat sufficient to bring about incandescence. In a short time you will have completely driven out the gas, and your fragment will fall in the form of a white powder. Analyzed, this powder is found to be lime, oxide of calcium, the substance which is frequently seen slaking, in the process of mortar manufacture, in the neighborhood of building houses. Marble is, therefore, a compound of carbonic acid and lime, or, as it is technically termed, a carbonate of lime. This is also the composition of limestone, of the minerals known as CALCITE and ARAGONITE, of the shells of shell-fish, the skeleton or "polypary" of the coral animal, and of true chalk, although much of the chalk of commerce is an artificial compound. This property of effervescing in minerals is possessed by most carbonates, and in our experiment the result proves that the avidity of the stronger acids for the lime was greater than that possessed by the carbonic acid, which had consequently been driven out. The test is a simple one, and serves as a ready means for

distinguishing limestones and marbles from rocks of an entirely different composition, which in some cases closely resemble them.

Very distinct though coral, chalk, and marble may appear, they have, nevertheless, in most cases, a common origin; they are the product of organic forces. This is self-evident in the first case, but not quite so in the remaining two. When, however, we take a quantity of finely powdered chalk, and place the particles in a drop of water under the microscope, it will be readily perceived that some of these particles possess definite shapes, the organic nature of which cannot for a moment be doubted. They are true shells, some globular, some spiral, and others elongated, belonging in most cases to the order of animals known as the FORAMINIFERA, about the lowest of the animal creation (see Chapter X, THE FOSSILS OF THE MARL). And where the complete form is not always recognizable the numerous fragments scattered about indicate that the organisms were exceedingly abundant, and that, as a matter of fact, they actually made up the great bulk of the chalk itself. Having determined this much, and reflecting that the deposits of chalk extend over an area of hundreds of miles in length, and measure in places hundreds of feet in thickness, it is no longer very surprising that marble, which in a general way resembles chalk hardened through pressure, and which shows much the same chemical and physical reactions, should have a similar structure. It is true that most pieces of marble powdered and placed under the microscope present no such appearance as we have seen in the chalk; there are neither perfect nor imperfect animal parts to be determined, and, therefore nothing to suggest an organic origin. On the contrary, even the naked eye will make out on the broken surface of a piece of marble the crystallographic faces of the mineral

calcite, showing the whole mass to be distinctly crystalline in its formation. But it is now well-known that marble is nothing but altered limestone—common limestone, in which, through the influence of heat and pressure, a true crystalline structure has been brought about. This being the case, it might be inferred that limestones which had undergone no material alteration in their parts would, when carefully examined, show distinct organic traces; the supposition is a correct one, for in almost every block of such limestone (at least when of marine origin) the microscope has revealed a sufficiency of more or less perfect shells, or other fragments of animal remains. It is concluded from this fact that all limestones, except such as may be deposited by fresh-waters, are of organic origin, and where, as in marble, no determinable organic traces are visible, this circumstance must be taken as an expression of the obliteration of parts rather than of their absence. And were any further proof of this position needed, it might be said that in many cases a distinctly fossiliferous, or non-altered, limestone, can be directly traced into the crystalline, or non-fossiliferous, marble. Limestones occur in all grades of structure, from the coarse shell-rock, "Coquina"—such as we now find forming along the Florida coast, where the component shells, or their fragments, are well marked out in size and character—to the fine-grained or compact varieties, in which, for the most part, the unassisted eye fails to distinguish individual forms. But few, if any, fossils have thus far been detected in the true limestones about Philadelphia, a circumstance, doubtless, in great part due to the metamorphism to which the rock was subjected during the process of lateral crushing. It is by no means impos-



Organisms in Chalk.

sible, however, that in the less altered deposits the outlines of some lowly types of organisms may yet be revealed by the microscope.

Perhaps the most striking physiographical feature in the region about Philadelphia is the long and narrow depression occupied by the limestones, known as Montgomery and Chester Valleys. Looking north from an eminence, like Chestnut Hill, the eye sees stretched before it a somewhat undulating monotonous plain, extending east and west to about the limits of vision, and across for a distance of some three or four miles. On either side rise elevations of moderate height, the rocks composing which are gneisses and sandstones, both on the north and on the south; the first rock to meet the limestone is the Cambrian sandstone, which dips beneath it along both boundaries, and consequently underlies the floor of the valley. The limestone rests on top, and is thereby proved to be of newer date. Although now occupying a comparatively narrow area there is every indication that at a former geological period it had a vast extent, and not improbably the sea depositing it stretched hence half across the continent. Being a rock readily soluble in water it has suffered greatly through erosion, and has left to the geologist only a mere indication of its former development. How far it rose above its present surface it is impossible to conjecture, but there can be little or no question that it at one time covered the sandstone ridge both north and south of it, from which it has since been removed through the time-wearing action of water. The relation of rock structure to the configuration of the land surface, or what is the same thing, scenery, is here beautifully exhibited. The rock (limestone) most readily yielding to the disintegrating forces has suffered more waste than the rock (sandstone) which by its compactness and insolu-

bility has been better able to resist the action of water; the one has weathered "low," whereas the other has weathered "high." These differences in the behavior of rocks, which underlie the manifold aspects under which the landscape presents itself to our eyes, are a guide-line to the geologist, fixing for him the positions of rocks possibly far beyond the limits of his own personal examination. The generally flat appearance of the limestone valley, as seen from the hill-top, may lead one to suppose that the rocks composing it were disposed horizontally, and that little or no disturbance had affected the positions which they had normally assumed when first laid down. That such is not the case, however, can be proved in almost every locality where the limestone is exposed in mass; the strata dip at a steep angle.

About a mile due north of Spring Mill, and reached by the main road connecting Spring Mill with Plymouth, are Potts' marble quarries, where one of the finest exposures of rock in the entire valley is to be had. Almost immediately after leaving the station, just outside the mill, the road skirts for a short distance a stream of transcendant purity, whose presence has given the name to the locality which it feeds. In the meadows lying about a quarter of a mile from here on the left of the road, opposite to where a branch road leads off to Marble Hall, are located the "Springs of Spring Mill," whose inspection will well repay a detour of a few minutes. At numerous points here in the meadow springs, as clear as crystal, rise from clefts in the underlying rock, evidently forced up by pressure exerted from some higher ground. Observe the dancing mounds of sand and earth, thrown up by the force of liberated bubbles of compressed air, whose intermittent action recalls the work of miniature

geysers and volcanoes. Rounded masses of "trap" rock, derived from a volcanic dyke that runs to near, and beyond, this point due east from Conshohocken, lie scattered about between the line of the main stream and the bounding fence of the meadow. Continuing on the high road, which runs for a short distance over a region of micaceous slates (HYDRO-MICA SCHISTS), whose relations to the surrounding rocks have not yet, perhaps, been very clearly determined, we reach almost immediately the line of the trap-dyke itself—which here crosses the road as a prominent swell, and whose debris (boulders) are scattered about along the hill-slopes and in the hollows—beyond which the white surface of the suddenly rising ground indicates the limestone country. At Potts' quarry the limestone, or rather marble, rises to a height of some 45 or 50 feet above the base line, forming a picturesque bluff on the west side of the excavation. The strata, which dip at a steep angle to the south, are alternately interbedded in white and blue layers, varying from several inches to feet in thickness. On the opposite side of the quarry, *i. e.* on the east, the wall of rock shows distinct lines of separation running at right-angles to the lines of bedding, probably brought about by a contraction of the rock. These are known to the geologist as lines of JOINTING, whose existence, as might naturally be inferred, materially facilitates the work of quarrying. Limestone deposits are especially favored by such transverse jointing. The operation of marble-splitting as here practiced is a very simple one. Holes of considerable depth, and disposed in a linear series, are first drilled into the rock; these are then filled with wooden wedges, and these in turn forced apart by means of iron bars being driven into them. The rock, not being able to withstand the steadily applied

pressure, is compelled to yield, and a split along the line of least resistance, or along the bedding planes, results.

A branch road starting from the cluster of houses situated just outside the marble cuttings leads off to the Ridge Road, following which (to the right) for a distance of about a mile and a half, we come to the largest and most imposing marble opening in the region. The locality, Marble Hall, derives its name from the circumstance that the marble in the vicinity is exposed in a long channel or "hall," which has been quarried vertically from the surface, and which extends downward to a depth of 200 feet or more. There are no true surface diggings. The strata here dip vertically, or nearly so, and the horizontally disposed lines which appear when looking into the hall, and which look like lines of bedding, are in reality jointing planes. The "breasts" of marble which unite the opposite lateral walls have been left standing in order to prevent a possible cave of the wall on either side. Owing to the great expense necessarily attendant on the hauling of rock from such a great depth, the works have been for some years practically abandoned, and large quantities of water allowed to accumulate in the bottom of the trough. The effect of deep clear water (150 feet) in absorbing the rays of light is beautifully shown in the dark, nearly black, color, under which the surface appears, a condition analogous to that which distinguishes many small deep lakes of elevated mountain regions.

The most extensive of the excavations about here is situated a short piece back of the country store; another, considerably smaller, and containing more of the bluestone, may be seen a little lower down on the Barren Hill road.

Just south of Marble Hall, forming the boundary between the

limestone and an adjoining narrow belt of slates (hydro-mica schists), is the line of the trap-dyke, which may be traced by its outcrop and a long line of boulders from beyond Mechanicsville, through Conshohocken, to this point, a distance of several miles. Following these boulders beyond Marble Hall for about two miles through the wooded slopes and over the open meadow we reach the Wissahickon, whose southerly course from Valley Green is deflected by the resisting barrier of trap, along whose northern face it flows for some distance, and then breaks through at a point shortly after crossing the Chestnut Hill–Lancasterville pike. The hard rock is seen to cross the channel of the water, and to continue beyond in a serial line of boulders of singular regularity. Observe the elevated rampart-like undulation of the meadow leading hence to the high-road, which marks the trap-ridge whence the boulders were originally derived, but which now lies buried beneath a capping of soil.

This most picturesque spot in the centre of the valley, whose air of quietude is only broken by the babbling of the brook, and the garrulous cawing of the crows in the tree-tops overhead, may be reached in about three-quarters of an hour from the toll-gate at the foot of Chestnut Hill by following the line of the Lancasterville pike. Immediately after leaving the gate we traverse a narrow tract where there are no exposures, and where, consequently, the rock formation is not indicated. But from our knowledge of the positions occupied by the Laurentian series both east and west of us, it is more than likely that it underlies the soil at this point also. The gentle swell ahead, with its distinctively white road-crossing, marks the narrow belt of quartz rock which we have already learned to recognize as Cambrian, and which, a short piece to our

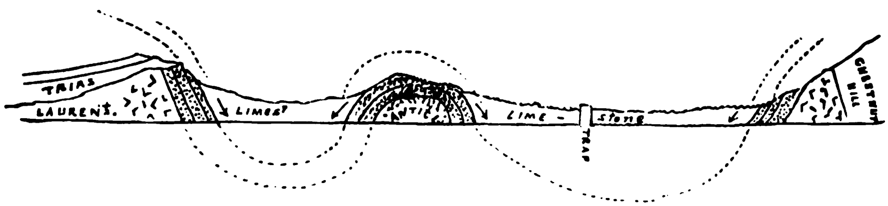
left (Convent), we had found dipping in the direction of the valley. At the foot of the hill we set foot upon the limestone. Where the limestone is exposed it can be seen to conform more or less closely in position to the sandstone; in other words, the beds decline or dip away from you, or in the direction of north. This disposition holds continuously until a short distance beyond the crossing of the trap-dyke (or Wissahickon), where the strata suddenly reverse their position, pitching steeply to the south. The extensive limestone openings situated on either side of the road a little this side of Williams' station, on the Plymouth Railroad, distinctly exhibit this arrangement of the strata. The rise immediately back of Williams' is formed by an arch or roll (anticlinal) of the underlying Cambrian quartz rock, which cuts off the limestone at this point, but permits it to reappear in a depression or trough (synclinal) on its further side, where it is again cut off by a second elevation of the older quartzite. This last is beautifully shown in the wooded hill to the left, opposite to where, as marked by a sign-post, a cross-road leads off to Flourtown. The rock, which inclines at an angle of some 60–70 degrees, is a tough reddish quartzite, ringing when struck with the hammer. The individual particles of sand of which it was originally made up—for when formed the rock was a true sandstone—have through the influence of pressure and heat been compacted into a homogeneous substance, along whose surface a granular structure is but barely, if at all, observable.

The elevated wooded ridge which runs for some miles almost due east from this point, and which, as the northern boundary of the limestone valley, forms such a prominent feature in the landscape, marks the outcrop of the Cambrian quartzite. Here, therefore, as on the south side, we have the same distinctive separation

of the rock of the valley from that of its boundaries. Continuing in the direction of Blue Bell we note a sudden and interesting change in the physiognomy of the country. The road we are traveling upon has assumed a reddish tint, which increases in intensity the further we proceed. Examined carefully it is seen that this red color is due to the powdering up of fragments of a shaly rock, quite distinct from the rock which we had last left. Evidently, we have struck a new formation, whose presence is indicated by the character of the superficial soil. For fully twenty-five miles across the country, and in a northeast and southwest line cutting completely across the corner of Pennsylvania and through the States of Maryland and New Jersey, this red-rock, known to geologists as the TRIASSIC shales and sandstones, extends uninterruptedly. Norristown is situated on it, and so are Bridgeport, Valley Forge, and Phœnixville. At almost every locality of its occurrence the strata dip uniformly to the northwest, and in many places they can be seen to rest upon either the Cambrian sandstone, or the valley limestone (Silurian), proving it to be of more recent origin.

Putting together the notes that we have taken in the field bearing upon the structure of the valley—say at about its middle part—and a little way beyond on either side, let us see what we can make of them. In the first place we have, beginning at the Chestnut Hill slope, the oldest of the rocks known in the region—namely, the Laurentian gneiss or syenite—which stand up nearly vertically, or decline somewhat in the direction of the valley. Following these, and resting on their northern flank, is the Edge Hill rock, or Cambrian sandstone, which dips beneath the limestone forming the floor of the valley. Just back of Williams' station this sandstone rises up in the form of a roll or arch (anticlinal), which separates the large

basin-like depression, forming the valley proper, on the south from a similar, but much smaller, depression on the north. Over this roll the limestone strata of the valley were at one time carried in a continuous sheet, but the waste which the rocks have suffered through mechanical disintegration and chemical solution has actually lowered their surface beneath that of the much more resisting



Section across the Limestone Valley.

underlying sandstone. The further boundary of the valley is formed by another rise of the Cambrian rock, which, doubtless, is the continuation of the rock which forms the roll back of Williams'. Finally, resting on top of this rock, and dipping at a moderate angle towards the northwest, we have Triassic red-shales and sandstone, and under them again, the Laurentian syenite. Evidently, judging from the position which the rock masses now occupy, they must have at one time risen to heights very much greater than what they now represent. The present outline of the land surface is due to the ceaseless wearing action of water and the atmosphere.

The history of the formation of the region is approximately as follows: On top, and not unlikely in a trough, of the ancient Laurentian gneisses were deposited the sediments of the Cambrian and Silurian seas, the former first, then the latter on top of these. How long a period of time intervened between the two depositions it is impossible even to conjecture, but it was, doubt-

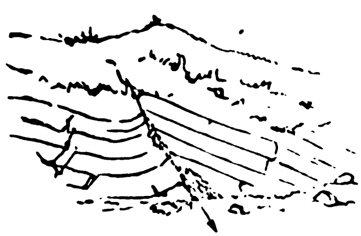
less, vast, and long enough to permit of very extensive alterations taking place on the land surface. We have stood upon the Cambrian beach at Willow Grove, and found it to be largely made up of blue-quartz pebbles, proving that the Cambrian billows swept the shores of Laurentian syenite, as the modern billows still do in the more northerly parts of the continent. The beach line does not, however, necessarily indicate that the sea stopped here. A submergence of the land may have carried the water still higher over its surface, burying deep the beach that was primarily formed; and not impossibly this is what actually took place. It is more than probable that the sea was a comparatively shallow one, but that it gradually deepened with the approach of the Silurian period, permitting of those vast accumulations of the remains of deeper-sea organisms which we recognize in the limestones and marbles of the valley. How far, and how continuously, this sea may have stretched toward the west it is impossible to say, but it may have been a thousand miles, or considerably more. Shell-fish, most of them of forms unknown at the present day, but, again, others very closely related to, and barely distinguishable from, types still living, had already attained a profuse development during this period; the coral-animals built up gigantic walls of rock, true reefs; and microscopic one-celled animals encased in shells, the Foraminifera, swarmed in countless multitudes within the ancient waters. But of all these varied forms of life, which are abundant elsewhere, not a recognizable trace is to be discovered about Philadelphia; their remains have been merged into the solid rock of the valley. An incipient vegetation had already in some parts begun to cover the land-surface, and lowly forms of insects, doubtless, tenanted the air. The singular trilobite, precursor of the modern king-crab, burrowed

in the soft mud of the oceanic littòral, while various shrimp-like creatures darted through the tangles of the gracefully-tufted stone-lily (crinoid). But of the higher forms of animal life, the fishes, amphibians, reptiles, birds, and mammals, we as yet know nothing; they appear later on the scene, the fishes first, the amphibians next, and the reptiles third, or in the direct order of their development.

The Cambrian and Silurian sediments were at first horizontal, or nearly so, but through a contraction of the crust, resulting in the upheaval of the entire mass, we had brought about that crumpling and folding whose effects are witnessed in the more or less vertical disposition of the strata, and in the alternation of anticlinal elevations and synclinal depressions, which are noticeable at Williams', and in the two valleys on either side. At a much later period, the period when the highest class of animals, the Mammalia, first broke upon the light of day, an estuary of the sea from the north, or possibly a river flowing from the south, deposited the red-shale and sandstone, but not before the land-surface upon which they were laid down had been very greatly worn; and probably about the same time, or a little later, a long line of volcanic or trap rock was forced through the crust, cutting the limestone in the form of a more or less continuous dyke. This dyke is still clearly marked out in a low, well-defined, rampart-like ridge, which traverses the valley longitudinally, and in a linear series of dissociated boulders which effect its continuation. From that time to this the region has probably been out of water, and has been undergoing those gradual modifications in outline which have resulted in producing its present features.

The exposures of limestone along the river front are numerous, and can be studied to advantage in the few miles that intervene

between Norristown and Conshohocken. In the first cut south of Norristown, Mogee's, the strata, which alternate in beds of various degrees of coarseness, and in shades of blue, white, drab, and red, dip steeply to the south, measuring an angle of about 40°. Immediately on entering the cut we notice on the right a vertical split in the rock, the strata on the opposite sides of which are not absolutely continuous with each other. There has evidently been a displacement, by which one side was dropped a piece below the other. Just what caused this FAULT in the rock it is impossible to determine, but it is, doubtless, due to an existing tension in the mass. Although the amount of displacement, or "throw," of the fault is here very insignificant, indeed, but barely appreciable, it is of the same kind as that which in many districts has elevated strata thousands of feet above their normal positions, or, as the case may have been, dropped them to the same extent. A more pronounced fault occurs in the red rock just beyond the further end of the cut, where the line of faulting, or "hade," runs diagonally across the beds. Observe that on the north side of the fracture the beds that have dropped are turned or "brushed" up against the line of the fault.


Fault near Mogeetown.

Continuing southward the beds become more and more compact, and are deficient in the sandy layers which are met with above. They evidently belong to deeper water than that which deposited the more northerly, or underlying, beds, and bear testimony to being deposited further from the shore-line. From a favorable point on the water a fine view may be had of the

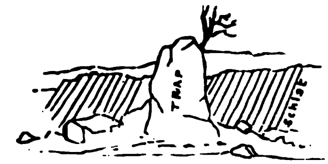
successive exposures following each other in the direction of Conshohocken, the strata in all cases dipping much the same way. The inclination of dip steadily increases, however, until at Conshohocken, where the limestone alternates with slaty layers, the angle measured is 60°. Back of the town, and directly opposite on the west bank of the river, a number of quarries have been opened, which furnish the well-known Conshohocken "bluestone," so extensively used for building purposes, curb-stones, etc. Much of the marble of our city that we see in door-steps, and otherwise, is obtained from the valley deposits, although not a little, especially that used in window-facings, is imported from deposits of nearly equivalent age occurring in Vermont and elsewhere. It is a singular fact that the limestone of the valley has been converted into marble principally on the south side, whereas on the north it has been more or less impregnated with magnesia, forming a magnesian limestone, or DOLOMITE.

VII.

"MUNDOCK:" A CHIP FROM VULCAN'S FORGE.

In West Conshohocken, a short piece up the river beyond the bridge, there projects from the hill side a peculiar bluish or bluish-green rock, rusted on the outside, which when struck with a hammer readily yields up its flake. It forms a prominent feature along the roadway, and cannot easily be overlooked. In structure it is finely granular, is decidedly tough, and manifests its power to resist disintegration and erosion in the manner it stands out where other less resisting rocks have been completely worn away. No trace of bedding is visible in the rock, which juts out as a promiscuous mass, although the reddish schistose rocks (HYDRO-MICA schists) on either side of it are very distinctly bedded, bearing the positive impress of water-action. The TRAP, for such the peculiar rock is called, has forced its way through these schists, as is evidenced by the fact that while it in itself stands up as a vertical boss, the strata both north and south of it dip toward and away from it in the same direction, or toward the south, and, consequently, have their continuity cut.

East of the Schuylkill the same hard rock reappears, forming at Conshohocken the prominent elevation immediately back of the station through which the Pennsylvania Railroad has cut its way. Wherever the trap crops out in large masses from the surface, boulders of the same rock lie



scattered about, usually weathered round in their outlines, and exhibiting their peculiar coating of rust on the outside. Indeed, in many places these boulders, which delight in the rather euphonious, but somewhat obscurely rooted, designation of "mundock" or "memdock," are the only indication that we possess of the presence about us of the parent rock itself, which may lie completely buried beneath a capping of soil. But even where so buried, the line of boulders, if such line exists, will usually disclose a more or less defined roll or swell in the country, possibly even a ridge, under which we may confidently assume that the tough rock rests. Such a roll extends east from Conshohocken for a considerable piece through the limestone valley, and may be readily followed with the aid of its outlying boulders for a distance of several miles across field and farm. The road connecting Spring Mill with Plymouth cuts through it about a half-mile north of the former station, some five minutes beyond the junction of the Marble Hall road. In a depression to the left of the road at this place, opposite to where a cluster of three or four houses marks a rise in the land, we find a heterogeneous assortment of boulders crowding the bed of a usually dry water-course, many of them evidently brought down from the neighboring heights, others, again, simply exposed as the result of the erosion which running water has

effected through the trap-ridge. Not all the rock masses lying about are true boulders; some of them instead of being rounded, as are the greater number, are columnar or prismatic in structure, showing 4–6 more or less perfectly developed sides. This structure is that which is assumed by certain bodies in passing from a molten or fluid condition to one of solidity, and is the expression of the regular contraction of the cooling mass. The same form of contraction is frequently exhibited by moist earth after it has been thoroughly baked by the sun's heat, it showing then a hexagonally or pentagonally checkered appearance on the surface.

We infer from the facts that are presented to us that our trap must have been at one time in the nature of a fluid or molten mass, which on solidification assumed the columnar structure, much the same (although in a very inferior degree) as we find it in the Giant's Causeway, Fingal's Cave, and other localities. Now, what is the nature of such a fluid rock, and where does it originate? Evidently, if water is in no way concerned in its deposition, if it bears the impress of having been at one time in a molten condition, and if it can be seen to traverse from below a mass of rock that had been formed before it, it must have its source in the earth's interior, where the high temperature is sufficient to fuse the most refractory rock substances with which we are acquainted.[7] In other words, it is the same kind of stuff as is thrown out by volcanoes, which we call lava. Trap and lava, then, are essentially synonymous, and both point to much the same kind of action having taken place beneath us. But while in the case of the lava out-throw we have certain other accompaniments of volcanic activity presented us, such as the volcanic mountain itself, the crater, cinders or scoriæ, and ashes, none such are found associated with the trap; its

outflow, evidently, was of a less paroxysmal nature than that which characterizes true volcanic outbursts. Furthermore, its energy was not expended specially upon any very limited area of the earth's crust, as that covered by a volcano, for example, but over a line of equal intensity extending over miles and miles. Indeed, it would appear that while in the case of a volcanic outburst the molten material is thrown out from the earth's interior by the expansive force of the contained aqueous vapor, the trap was merely thrown or squeezed out by a shrinkage and fracture in the crust. At any rate, there can be no doubt that the trap comes through a long, and comparatively narrow, fissure, which when choked with the outflowing material is known as a DYKE. Our long line of trap, therefore, is a true dyke, essentially similar to the dykes that traverse the core of a volcanic mountain. Of a similar nature are the outcrops that we find in Chester and Bucks Counties, the parallel ridges of north-central New Jersey, known respectively as First (" Wachung," " Springfield," or " Orange "), Second, and Third Mountains, and the vertical wall of rock which extends along the lower Hudson River for a distance of twenty or more miles, known as the Palisades. In cooling in the fissure the rock acquires the columnar or prismatic structure, such as we have found it in our rambles. It very generally happens when the ejected material is abundant that it rises beyond the lip of the crevice, and then overflows the rock-masses lying on either side, stratifying over them. That such has been the method of deposition in some parts of the region about us, as in northern New Jersey for example, is abundantly proved by the masses of red sandstone which can be seen outcropping from beneath the trap, as in the quarries on the slope of Orange Mountain, or at the imme-

diate base of the Palisades. In such overflow-traps the columnar structure is frequently beautifully exhibited—indeed, only here is it found in absolute perfection—as we see it in Fingal's Cave and the Giant's Causeway, where it attains its grandest proportions. But even along the slope of modest Orange Mountain, N. J., the recently become famous "Mountain Colonnades," situated a short piece back of the town of Orange, will not be found lacking in grandeur, or unworthy of a place beside their more celebrated trans-Atlantic prototypes.

At this exposure, which measures 750 feet in length, and 98 feet 2 inches greatest height above the base or working line, the rock quarried is the familiar "greenstone" (trap), the material of the Palisades quarries, which until recently supplied the city of New York with a great part of the Belgian paving blocks. That which immediately arrests the attention of the visitor to the quarry is the magnificient display of the columnar structure, thousands of basaltic columns of the hexagonal and pentagonal pattern appearing, if not in the absolute perfection of the similar columns of the Giant's Causeway and Fingal's Cave, in a perfection but very little inferior to these. The base or lower half of the exposure is made up of a vertical palisade of 120 or more columns, measuring individually from 15 to 40 or 42 feet in height, and from 3 to 5 feet, or even more, in thickness. Towards the middle the height of this palisade has been greatly reduced, partly through the failing of the columns themselves, and partly through the artificial destruction that has here been effected. Above this line, which in some parts is sheared off as evenly as though it had been manipulated by the hand of man, the columns suddenly diminish in size, and instead of retaining the vertical position, now arch diagonally upward and outward, meeting

from opposite sides to form an apex immediately under the highest point of the exposure. Many of the columns rest horizontally, or nearly so. Beyond the horizontal layer, what may be considered as a third series of columns makes its appearance, and here, again, the vertical position is assumed. The material of the glacial drift, as indicated by a heterogeneous assemblage of pebbles and boulders, rests on top, forming the subsoil of the region.

The first impression produced upon the casual observer by the complete exhibit is one indicating disturbance; the arched or diagonally inclined, and apparently disturbed, position of the columns of the upper and inner portion of the mass, would seem to imply an upheaving thrust from below, just underneath the apex. In other words, it would appear that we were over the seat of some subterranean disturbing force, or in the centrum of volcanic action, and, therefore, in the position of a true vent. But had there been such a thrust as is here implied, we should expect to see its effects revealed in a fracture or dislocation below the top, whereas none such is apparent. On the contrary, the continuity of the columnar mass is fully as well marked on top as anywhere else, and no indications of special disturbance are anywhere manifest. We are, hence, forced to the conclusion that the irregular and apparently disturbed position of the columns is not in reality due to any disturbing agent, but is merely the result of peculiar conditions of cooling and solidification of the original molten substance (lava). In other words, while some portions of this molten lava "crystallized" into vertical prismatic columns, other portions "crystallized" horizontally, and in all the intermediate planes lying between the horizontal and vertical. This irregular method of columnar formation is the result of irregular convection and radiation of heat, and

consequent irregular solidification. The deep layers, where the loss of heat was effected slowly through conduction with the underlying rock, produced stout vertical columns; the more superficial layers, where radiation was most active, frequently produced horizontal columns, while between the two were found columns occupying all the intermediate positions.

Our own modest dyke, which crosses the Schuylkill at Conshohocken, and which in West Conshohocken can be measured along a width of two hundred or more feet, appears to represent approximately the same period of activity during which the parallel ridges of New Jersey were upthrown—a period which had already witnessed the deposition of the Triassic red shales and sandstones. It is difficult to picture to one's mind this period of long-ago, when through a series of parallel fissures by which the crust of the earth was rent, the fiery mass of the planet's interior welled forth in sheets of liquid rock. It was a time when a more nearly tropical vegetation than now exists in the region covered the land surface; when the members of the feathered creation, if they at all existed, were as much reptiles as birds; when giant reptiles haunted the seas and wallowed in the marshes; and when the first suckling animals, the Mammalia, were put upon the scene. The solid breastwork of rock, which to the eye of the railroad engineer is nothing but a mass of hardness, is the record of events of which Etna or Vesuvius may well have been proud.

VIII.

BROWNSTONE FRONTS AND JERSEY MUD.

That rock masses undergo rapid disintegration through atmospheric agencies everyone will discover to his discomfort who ventures to our red rock country immediately after a heavy rain. The turbid streams speak for themselves, and require no commentary to render their text intelligible. All through a tract of some twenty to thirty miles width, extending from Norristown northeast and southwest through the corner of the State to the New Jersey and Maryland boundaries, and far beyond, we find red road beds, red soil in the farms, and standing pools of red water. They all bespeak the character of the rock out of which the country is built, and are the indices of the destruction which it is continuously undergoing. From this region the Schuylkill and its tributaries derive much of their contained sediment, and to it, likewise, the Delaware is indebted for much that it possesses. On the Jersey side of the Delaware the TRIASSIC red shales and sandstones form a continuous belt extending from Trenton to opposite the city of New York, where they underlie the cliff formation known as the

Palisades. They occupy the lowlands at the foot, and toward the east, of the first ridge of trap hills ("First," "Wachung," or "Orange" Mountain), upon which are situated Elizabeth, Plainfield, Newark and New Brunswick—the region of the proverbial red mud, which forms such a distinctive feature in the landscape of this section of the State.

Throughout the tract covered by the Triassic rock exposures are numerous, and almost everywhere the strata, consisting of alternating beds of conglomerate, sandstone, and shale, hold a nearly uniform position, dipping to the north or the northwest. This disposition of the layers is beautifully exhibited in the quarry situated near the southern extremity of Norristown, along the main street, where the rock in different degrees of hardness and resistance presents a series of massive beds dipping at a low angle (six degrees) to the horizon. Observe the alternations of earthy (shaly) and pebbly layers, indicating the different conditions of deeper and shallower water, and proximity to the shore line, under which the deposits were laid down. In many of the layers the red resulting from the oxidation of the contained iron has been more or less removed, and the rock rendered of a gray, or even nearly white, color. We see here, therefore, that little or no dependence is to be placed upon color as a criterion in the determination of rock formations.

A short distance to the south of our present position, in the Mogeetown cutting, the red rock is seen overlying the steeply dipping limestones of Silurian age. While, as we have just observed, the sandstone dips to the north, the limestone dips in the contrary direction, or to the south, and consequently we have an example of UNCONFORMABILITY presented between two formations.

This condition may be still better studied at Port Kennedy, a short piece back of the railroad station, where heavy masses of both the Silurian and Triassic formations have been exposed in quarrying. How has it happened, you might ask, that two such widely separated formations as the Silurian and Triassic should lie contiguous to each other? What has become of the Devonian, Carboniferous or Permian? The answer is simple enough. Ever since the close of the Silurian period, when the limestones were laid down, this portion of the country has been above water, or dry land, and as such has received little or no deposit of sediment on top of it. With the beginning of the Triassic period, however, a vast sheet of water, apparently in great part fresh, and not improbably representing a great river flowing from the south, or an arm of the sea extending southward from the region of New York, again covered the land, and deposited the masses of mud and sand which we recognize in our red shales and sandstones. We have here the proof of a big break, such as has been explained in the second chapter. It is true we have the alternative for supposing that the more ancient formations did exist here at one time, and that they may have been simply washed away, but this is very unlikely, seeing that not a vestige of such existence has been retained.

But why do we surmise that the water which laid down these rocks was in great part fresh, or in any way different from that which deposited the limestones and Cambrian sandstones? For, in the first place, the very narrow tract covered by the rocks in question, which reappear neither to the east nor to the west, and which from their position we know not to be covered by any newer marine deposit, is almost proof positive that they could not have been laid down in the trough of the sea, otherwise their extension

would have been very much greater. But if they occupy the position of an arm of the sea extending into the continent, that arm must have been rendered largely fresh through the admixture of water thrown into it from the land surface. On the other hand, the water may have been entirely fresh, or nearly so, representing a river flowing to the sea, rather than an arm of the sea extending into the land. On this point, however, such evidence as we possess is very unsatisfactory. The fossil remains occurring in the formation are exceedingly few, and give us but little clue to its character. The scales and dermal armor of fishes belonging to the now nearly extinct group of enamel-plated ganoids—the group to which the modern sturgeon and gar-pike also belong—prove that fishes inhabited the water, but they tell us little or nothing as to their habits, whether inhabitants of fresh or salt water, or a mixture of both (brackish). The same is true of the few forms of shells which have been found in the neighborhood of Phœnixville, whose structural features are too imperfectly preserved to permit of an absolute localization of the group; in a general way, however, they appear to be most nearly related to the fresh-water naiads (*Unionidæ*). Such plant remains as have been found in the formation belong in great part to the order *Equisetaceæ*, whose modern representatives, the horse-tails (*Equisetum*), modestly lift their heads to a height of only one or two feet above the surface, but whose ancient precursors, the calamites, rose to the dignity of noble trees. Their remains, although not abundantly spread throughout the formation, are very numerous in certain localities, and appear indicative of a luxuriant vegetation—a vegetation of jungles and marshes, whose recesses were inhabited by giant salamandroid animals (*Labyrinthodonts*), and no less formidable reptiles. The footprints of

these singular creatures have been indelibly impressed upon the ancient sands, and with the associated ripple-marks and raindrop-impressions bespeak in so many words not only the history of their time, but the history of a moment.

The limestone at Port Kennedy has been eaten out in two or three places to form fissures or caverns, the largest of which, now unfortunately covered in, has served as a receptacle for the washed-in remains of many large quadrupeds, mostly extinct, which have left their bones behind them to attest their fate. Such have been the giant sloths (*Megalonyx*, *Mylodon*), mastodon, tapir, bear and panther (?), whose remains were exhumed here some fifteen years ago. Just when the caverns were formed in the limestone it is impossible to say, but, manifestly, their age has nothing to do with the age of the limestone itself, since they could have been formed at any period since the deposition of the limestone. Owing to the ready dissolution of this rock through percolating water it is admirably adapted to the purposes of cave manufacture, and as a matter of fact we find that nearly all the extensive caves of the world—the Mammoth and Luray caves, as examples—have been formed in limestone strata. Nor, in the second place, need the period of the deposition in the cavern have anything to do with the actual age of the cavern itself, since here, as before, said deposition may have taken place any time since the formation of the cave. In the instance before us the faunal remains are clearly of late Tertiary age.

Almost everywhere where the Triassic deposits are met with they present much the same characters—conglomerates, grits, sandstones, and shales. The further we remove from the border of the area which they cover, the finer, as a rule, becomes the material of which they are composed, as might naturally have been expected.

In some places the pebbles are extremely coarse, measuring several inches in extent, and give to the mass a knotty appearance; where capable of a fine polish the rock is extensively used for architectural purposes, and may be frequently seen in the familiar mottled stone known as "Potomac marble." The pillars in the old Hall of Representatives in the Capitol, at Washington, are made of this stone, a calcareous conglomerate. Where the shale has come in contact with the injected molten trap a marked alteration in the character of the rock, resulting in its hardening or "baking," is frequently noticeable. This we see in the black rock of Gwynedd, a tough material which has by some been supposed to represent a carbonaceous deposit. Many of the aboriginal implements found in the region of the Delaware are manufactures of baked shale (ARGILLITE). The sandstones, when of a sufficiently homogeneous texture, and sufficient thickness, are extensively quarried, and put to building and paving purposes; but in our own city, as well as in New York, where the "brownstone fronts" constitute such a monotonous feature in metropolitan architecture, the rock is obtained in principal part from the deposits of equivalent age occurring on the Connecticut—the famous foot-printed sandstones of the Connecticut valley. A lighter-colored building stone—"freestone"—obtained from some of the New Jersey quarries, is held in considerable esteem by builders.

A remarkable ore-belt, yielding the ores of copper, lead, and zinc, which has been opened at various points between Valley Forge and Phœnixville, on the Perkiomen a short distance above Pauling's Bridge, and elsewhere in Pennsylvania and New Jersey, lies in partial association with the red sandstones, and with the underlying gneisses. That the lodes date their formation (injection) to

a period subsequent to the deposition of the Trias is proved by the circumstance that they cut some of the trap-dykes, which in themselves are intrusions in the sandstones and shales. Many beautiful specimens of minerals, such as GALENA (sulphuret of lead), CERUSSITE (carbonate of lead), PYROMORPHITE (phosphate of lead), ANGLESITE (sulphate of lead), BLENDE (sulphuret of zinc), CALAMINE (silicate of zinc), MALACHITE and AZURITE (green and blue carbonates of copper), CHALCOPYRITE (sulphuret of copper and iron), PYRITE (sulphuret of iron), etc., may still be obtained from the output of what is known as the "Wheatley Mine."

Most of the fossils from the Trias of Pennsylvania have been obtained at Phœnixville and Gwynedd. These comprise the scales of ganoid fishes, the impressions and bones of several species of reptile (*Clepsysaurus*, *Belodon* [crocodilian]) and amphibian, a few undeterminable shells, crustaceans (*Estheria*, *Cypris*), the larval case of an ancient May-fly, and various plants (calamites, ferns and allies [*Voltzia*] of the cypress).

IX.

IN THE MARL DIGGINGS: WHAT THE GREENSANDS OF NEW JERSEY TEACH US.

The traveler on the Delaware will probably have noticed near Bordentown, and at various points on the east shore south of Trenton, the rather unsightly banks of party-colored earth that rise steeply from the water's edge. They add, indeed, little to the scenery, but, nevertheless, constitute a prominent landmark by reason of their peculiar tints. The same red, or reddish, and white banks follow the line of the Philadelphia and Baltimore railroad for a considerable distance between Wilmington and Baltimore, and in the last-named town crop out in many of the streets that have not yet been built over. West of the line of the railroad, if these deposits extend at all, they extend to only a very short distance, for we almost immediately strike the belt of gneisses and schists with whose features we have already become familiar about Philadelphia. Connecting the points of outcrop of these colored clay beds, from the Delaware to Baltimore, we find that the resulting line conforms pretty regularly to a line that might be run almost due southwest from near Trenton to Baltimore; and this same line, marking the

same physiographical features, may be continued further to the northeast to Amboy, and southwest to the outskirts of the city of Washington. We have here defined the border-line of an ancient sea, and the deposits that lie immediately east of it are the deposits of that sea. These are quite distinct from anything that we have thus far seen west of the Delaware. In the first place, the rock is soft and yielding, a clay, or sand, or a marl, and not of the hard substance of the crystalline rocks, or the sandstones, or limestones; secondly, the beds, wherever they are exposed, show no signs of that crumpling or folding which so eminently distinguish the Philadelphia series of rocks, but, on the contrary, they still occupy a position not very different from that which is occupied by the deposit now forming out at sea east of the New Jersey coast. In other words, they dip or slope gently toward the sea (S. E.), with a fall of about 30–35 feet to the mile. The direction of dip having been determined, it is evident that the beds appearing on the river front, or those which are removed furthest to the west, are the oldest of the series, for from their position they can be clearly shown to pass *under* the beds situated to the east, and, therefore, to underlie them.

The south Jersey tourist will have frequently noticed in his rambles, all along the region of farms, dumps of a green or blue, or more rarely, black earth, which in texture and appearance departs very widely from the general character of the soil upon which it rests. This "marl" or "marl sand," which is dug in a series of irregularly scattered "marl pits," contains an abundance of phosphatic material, and is, hence, extensively used as a fertilizer. Although it has now been in use for a period of forty years, or more, its place has of late been in a measure usurped by the preferred phosphate earths of

South Carolina, which belong to a very much newer epoch of geological time, and whose development comprises a considerable tract along the Atlantic coast. Just how the phosphatic element was introduced into the rock is still a matter of doubt, but it may have been, at least in part, derived from the decomposition of bone. Here, in New Jersey, different names, indicative of the distinctive coloring, have been given to the marls; thus, we have green, blue, chocolate, and black marls, and where the remains of shells are very numerously imbedded in the earth we call it a "shell marl." This use of the term marl is not strictly correct, for in its ordinary acceptation the word is intended to indicate a mixture of clay and lime. Except in the shell layers, lime is present in only insignificant quantities, and even in the green beds, which are those most extensively dug for fertilizers, the quantity is too inconsiderable to permit of special importance being attached to it. Collectively, the green beds are known as "greensands," but the designation of sand is no less incorrect than marl, for, as you can readily determine by placing the substance in your mouth, the particles of true sand entering into the composition of the earth are comparatively few in number, and by no means make up its bulk.

One of the most instructive excursions to the New Jersey marl regions can be made via the West Jersey or Camden and Cape May Railroad. Select a dry day, and one that has not been immediately preceded by rain, for if opportunities anywhere exist for sticking in the mud they are among the marls. But beware of a too cloudless sky, if your excursion is planned for summer, as shade is a circumstance not to be despised when the thermometer ranges high into the nineties, or reaches the hundred line. Provide yourself with hammer and garden-trowel, both of which will be of

service. At Wenonah station, a few miles south of Camden, we engage a team (or secure a seat in the mail coach), and drive to Mullica Hill, distant some six or seven miles. Beyond the village of Mantua the road becomes heavy, a deep gravelly sand in some places seriously interfering with rapid locomotion. Much of the yellow gravel is fossiliferous, and in some of the pebbles the structure of corals can be very clearly made out. Just where these pebbles came from it is impossible to state, but from their contained organic remains we have no hesitation in affirming that they are the disrupted parts of some very ancient rock formations, Silurian and Cambrian, which have been washed hither by oceanic currents during a period of land submergence. Here and there along the road the banks on either side consist largely of red sand, whose peculiar color is given to it by the iron which it contains. Where the roots of plants penetrate this sand you will observe in many places that the red color has been removed. Some physiological action connected with the growth or decay of the roots has evidently dissociated the iron, and the sand is rendered colorless or white. We frequently meet with this condition in red rocks, where immediately about the plant impressions irregular blotches of white appear.

Just before entering Mullica Hill an off-road descends to the left, following which we are presently brought opposite the rather unsightly bank to which reference is made in the first chapter. The rock has here crumbled badly, and the lines of bedding or stratification have been completely effaced. From underneath the top-soil, if you are fortunate enough in reaching there, detach with a smart blow of your hammer a portion of the crusty layer. Examine the released mass, and it will be observed

that it is everywhere indented with shell impressions, and that, in fact, it is itself largely made up of shells of one kind or another, or of their interior moulds ("casts"). You will have no difficulty in recognizing among the larger fossils two such forms as are figured on Plate V, under the names of *Exogyra costata* and *Gryphæa vesiculosa*, both of them members of the oyster family, the one with a laterally-twisted beak and a ribbed shell, and the other "vesicular" (like a bladder) in form, and with a generally smooth shell. These two shells, which, by their numbers, constitute a true oyster bed, really make up the great mass of the crust, and their dismembered parts can be found scattered all over the face of the bank and along its foot. Another very plentiful impression or cast, much resembling in shape and size a cigar, is that of the *Belemnitella mucronata*, a member of the cuttle-fish order of animals, whose actual remains are here but very seldom met with, although they are very abundant in some of the marl pits, and may be found sparingly along, or in the bed of, the stream that here courses through the adjoining meadow.

At the beginning of the bank, just back of the miller's, where the rain has washed the surface into a series of gulleys, you will find near the top the casts of a number of snail-shells (gasteropods), and possibly, too, the casts or impressions of one or two species of bivalves, in addition to the oysters already noticed. All in all, there have been obtained at this locality some twenty to twenty-five distinct species of fossils, not one of which is found living in the seas of the present day. Evidently, the fauna, to be so different from anything now existing, must be of very ancient date, and not unlikely a million of years may have elapsed since it became extinct. Geologists tell us that it belongs to the Cretaceous period,

a period of time long antedating the introduction of the earliest of the quadrupeds that now roam the land, and when a vegetation of deciduous plants, or such as annually shed their leaves, like the oak, beech, alder, willow, birch, and laurel, first succeeded to the growth of palms, cycads, and ferns which preceded it. Monster reptiles of the most uncouth forms, some of them inhabitants of the oceanic deep, others denizens of the marshy jungles, were the "lords of creation" for the time, and none but their own kind was there to dispute with them the possession of either land or water. Their remains, in the form of vertebræ, teeth, and more or less complete parts of the skeleton, are abundantly scattered about, and give to the world evidence of sanguinary conflicts between beast and beast, which have probably never been matched, either before or since, in the history of the earth. Just at Mullica Hill itself vertebrate fragments are not frequently met with, and when found they are usually the tooth and double-disk vertebra of a species of shark. More favorable localities are the pits, or marl diggings, especially in the season of work, when large quantities of the earth are thrown down, and can be leisurely examined. The commoner finds are fragments of the carapace of one or more species of turtle, the teeth and vertebræ of the crocodilian *Hyposaurus*, and the similar parts of what might be considered a veritable sea-serpent, the *Mosasaurus*.

At the further end of the bank is Raccoon Creek, passing which on the main road we proceed almost due east for a distance of about three-quarters of a mile, and then turn sharply to the right on the road leading to Mr. Stratton's. Just before reaching the house which marks the entrance to Stratton's pits a road leads off to the right into a depression where considerable marl is being

dug. The differently colored beds—the "blue," "green" and "black marls"—are here very clearly shown, and it may be well to descend and examine this structure, if for no other purpose. Fossils are very scarce. Note how very sharply the various layers follow each other, and how clearly the top soil and gravel are cut off from the formation. A short distance beyond the house a farm-road leads off to the right, which in a few minutes brings us to the declivity of the Stratton's pits proper. Following the scantily marked out road which descends into the hollow clear across we come face to face with a vertical section of the "marl" beds, in which the general structure of the formation is beautifully exhibited. Those who have never before seen a fossiliferous stratum, and who, therefore, have no clear conception of the important part which animal life has played in the manufacture of the earth, will here experience that peculiar thrill of enthusiasm which attends the first acquaintance with one of the grand truths of nature. Myriads upon myriads of shell remains, some perfect, others fragmentary, solidly build up a layer four to five feet in thickness, packing the rock so closely as to practically exclude all intermixture of foreign substances. We have here a true shell-rock formed through a process of slow accumulation of shell upon shell, and requiring in its formation not improbably thousands of years. Hundreds of thousands, possibly millions, of years have elapsed since the animals of this period lived and flourished, the most varied vicissitudes of nature have visited the surface of the globe, and yet many of the shell fragments appear as fresh and perfect as though they had been deposited but a few years ago. They tell the tale of an ancient sea occupying the floor where you now stand, whose borders were removed probably not more than a few miles

further inland; of an elevation of the sea-bottom which laid them high and dry; and of a long-continued period of repose, which left them in a position practically undisturbed since the period of their first deposition. What more imposing chapter in the history of a planet could readily be found?

It will be observed that the shell-layer is made up almost exclusively of two kinds of shells. One is an oyster (*Gryphæa vesiculosa*), identical with one of the forms whose acquaintance we made at Mullica Hill, and which can be recognized by its irregular outlines; and the other, a member of the class *Brachiopoda*, in which the outlines of the shell are quite regular, and which has the extremity, or "beak," of the larger valve perforated. In the majority of cases this last species, the *Terebratula Harlani*, has only the anterior halves of the two valves preserved, which remain attached to each other by means of the interlocking teeth that are developed on the hinge. It will be observed that the Terebratula and oyster each occupy distinct zones of the shell-layer, although numerous individuals occur mixed together. Nowhere in the exposure before you will you find a trace of either the *Exogyra* or the *Belemnitella*, and, although we have the *Gryphæa*, we naturally conclude that the age of the formation or "horizon" at this point differs somewhat from that of the Mullica Hill outcrop. This has been variously proved to be true, and the Mullica Hill beds, included in the "lower marl" series, have been shown to be the older of the two, and, consequently, to underlie the shell layer of the "middle marl" series. The suddenness with which the shell-layer is cut off on top is very surprising, and proves that there must have been some great physical alteration of one kind or another which prevented a continuance of the life of

the period into the period next succeeding. For how, otherwise, can we explain the total, or almost total, absence of either of the two shells from the overlying deposit? In this deposit, instead of the shells, we find principally the minute spines, and occasionally plates, of several species of sea-urchins, echinoderms, and more rarely, the matted tubes, two to three or more inches in length, of the burrowing shell-fish *Teredo tibialis*. This appears to be the top, or very nearly the top, bed of the Cretaceous formation, and not improbably the stratum above, which is riddled with the tunnels of the bank-swallow, already forms part of the Tertiary series.

Let us now for a few moments turn our attention to some of the older beds, the greensands. How little do we suspect that in this apparently non-fossiliferous, and very commonplace looking deposit we have presented to us one of the marvels of nature! A little of the material spread on the palm of the hand shows us that the earth is made up of two distinct kinds of ingredients—common gray or white sand, and little rounded pellets of a greenish substance which mineralogists call GLAUCONITE. The latter, which is a silicate of iron and potassium, preponderates to a very great extent, so that the whole mass at first sight appears as though it were made up of it exclusively. Now, what is the nature of these microscopic particles? What history do they unfold? All through the mass of the Atlantic and Pacific Oceans, down to a depth of some thousands of feet, multitudes of delicate little creatures, some fairly large, others of about the size of a grain of pepper, pass a life of luxurious comfort, rocked hither and thither by the surface billows, or gently floated on the currents of the deep. Their claim to being considered organisms lies in the possession of a tiny bit of

animal jelly-like substance, known as *protoplasm*, and an encasement to this in the form of a lime or calcareous shell. No trace of any organ appears whatever—there is neither mouth, stomach, heart, nor nerve—and yet the creature passes through the cycle of life with a full performance of the usual functions of assimilation, growth, and reproduction. There are no fixed locomotory appendages, but the animal possesses the power of throwing out at will peculiar processes of the body substance, called *pseudopodia* (false feet), which subserve the double function of locomotion and prehension. These gain the exterior by penetrating through a series of pores in the shell, whose general presence has given to the class of animals which they characterize the name of Foraminifera, or pore-bearers. We know of but few kinds of animals that are simpler in structure than the Foraminifera, and one of these is the universally distributed proteus-animalcule, or *Amœba*, which, in fact, only differs from the true Foraminifera in the absence of a shell.

In its simplest form the foraminiferal shell is nothing but a tiny hollow sphere, in which the protoplasm, or active animal substance, is lodged. In the more complicated forms this primitive sphere buds out into a number of additional spheres, which gradually increase in size from the oldest to the newest, and which may develop either one in advance of the other in a straight line, or what is more usually the case, in one or more circles around the initial sphere. A very complex arrangement of chambers may thus be built up, especially if the system of development has proceeded along more than a single plane. Conceive now that some of these microscopic organisms have reached the limit of their natural existence. The living animal substance decays and shrivels up, and sooner or later falls out of the shell, which, no longer upheld by

the vital forces, now slowly enters upon its journey to the oceanic bottom. However long it may take to accomplish its descent, possibly in some cases months, or even more, one thing is certain, that there is a continuous rain of descending particles all through the oceanic mass, as is proved by the accumulation of white shell mud, the "Atlantic" or "Globigerina ooze," over the bottom. How thick this shell mud may be, which is largely made up of the remains of the foraminifer *Globigerina*, it is impossible to say, but there can be no doubt that it is exceedingly thick, and that it represents a downpouring extending over not improbably hundreds or thousands of centuries. During the progress of their descent, and after, the empty shells, or at least a large proportion of them, become filled in with the green mineral glauconite, whose elements are contained in the sea-water, which thus forms perfect casts of the interiors of the shell-chambers. If now, by some means, the shells themselves should be entirely dissolved away, our only evidence of the former abundance of animal life would be in the nature of these interior moulds or casts. That such a dissolution, possibly assisted by the carbonic acid contained in the water, does actually take place is proven beyond doubt, as over a considerable part of the oceanic floor we find no shells, but merely a deposit of green glauconitic earth—the various forms of shell castings.

It might little be suspected that the greensand of the New Jersey marl pits is of this nature, but it is. The microscope has revealed in the little green pellets that are barely distinguishable to the eye the same clearly defined organic forms that lie buried in the oceanic abysses, the same that in their tiny habitations are wafted noiselessly through the currents of the mighty deep. What grander realization of the prodigious effects produced by

apparently insignificant causes could we possibly obtain? That this mass of green earth, at one time the floor of an ocean, should have been built up of countless myriads of microscopic germs is, indeed, a vast conception, and one which the human mind may be readily pardoned for in not immediately accepting. Between 20 and 30 distinct species of *Foraminifera*, largely of the types that still inhabit the sea, have been described from the New Jersey greensand.

At the further end of the pits, to the left as you face the cliffs, a mass of bluish earth, largely made up of well-defined crystals of the blue mineral VIVIANITE (a phosphate of iron), has been thrown up, and is quite accessible. The same mineral, sometimes known as MULLICITE, also occurs at Mullica Hill, where its white or blue fibrous crystals fill in the spaces left by the decomposition of the Belemnitella shell ("guard"). Before leaving Stratton's it will be well to run over with your trowel the heaps of green and blue marl that lie scattered about, as you are almost sure to find here a number of delicate, sharply-pointed sharks' teeth (*Lamna*), or vertebræ, and the casts, colloquially termed "squirrels' heads," of the bivalve shell *Arca*.

The return journey to Wenonah may be made by way of the "West Jersey Marl Pits," situate not far from Barnesboro, which are among the most extensive of the kind in the State. Approximately the same section is seen here as at Stratton's, but the beds are not so readily accessible, owing to accumulations of water. On a bank which at the further end separates the excavations from a running stream of water there were formerly found great quantities of the cigar-shaped guards of the *Belemnitella*, but these have in great part been swept away, although, doubtless, perfect specimens

may still be had if properly sought after. One of the finest exposures of the strata is to be seen in the series of pits which extends from about a mile back of Barnesboro to Hurfville, and again at Blackwoodtown. The different layers, in their various shades of red, green, blue, and white, are beautifully exhibited, and form a very picturesque element in the landscape. In some places the shell bed has been completely deprived of its shells, whose former presence is now only indicated by cavities corresponding to their outlines. Numerous marl diggings occur throughout the region, but in their general character they show no marked deviation from the pits which we have been examining, and, therefore, require no special consideration.

X.

THE FOSSILS OF THE MARL: OR LIFE IN THE CRETACEOUS PERIOD.

The most conspicuous feature of the fauna of the clays and marls is constituted by the shell-fish (Mollusca), whose remains belong to several distinct classes:—

1. LAMELLIBRANCHIATA or ACEPHALA, which comprise the commoner forms of mollusks, have a bivalve shell, such as the oyster, clam, or cockle. The animal is always provided with a shell composed of two (occasionally more) valves, which are situated laterally on either side of the body. These valves are with very few exceptions (as in the case of the common oyster, the thorn-oyster, and comb-shell) "equivalve," *i. e.*, of equal size, a character which readily distinguishes them from the shells of another class (Brachiopoda) presently to be described. The beak (umbo) of the shell is usually situated on the anterior side (exceptionally in the middle in the "comb," or scallop, and some other forms), and, therefore, if a line be drawn uniting it with the centre of the long margin along which the shell opens, it will divide the valve into two unequal lateral parts, a smaller anterior

and a longer posterior part; the shell is then said to be "inequilateral." This character also serves to distinguish the shells of this group from those of the group above referred to. On each side of the body of the animal, protected by the overhanging mantle, are two delicate lamellar organs, known as gills, which subserve the function of respiration.

The most abundant of the lamellibranchiate forms found in the marls are the two species of oyster—*Exogyra costata* and *Gryphæa vesiculosa*—already mentioned as occurring in the region of Mullica Hill, and the "squirrel's head" (*Arca*). The first two are especially distinctive of the formation, and they are not only found in New Jersey, but in almost every State along the Atlantic and Gulf borders in which the Cretaceous deposits are extensively developed. The genera *Exogyra* and *Gryphæa* have thus far never been found in any formation newer than the Cretaceous, and, therefore, serve as important landmarks to the geologist in the determination of his horizons. Two or three smaller species of oyster, a thorn-oyster, and several other forms figured on Pl. V, are also met with, but they are of much rarer occurrence than the preceding.

2. Brachiopoda. The members of this group are also provided with a bivalve shell, but the valves instead of being placed relatively to the animal on the two sides (or laterally), occupy positions respectively in front and back of the body. The shell is almost invariably inequivalve, and the valves just as invariably equilateral. The beak of the larger valve is generally perforated by a round foramen, through which a bundle of muscular fibres (peduncle), serving for the attachment or anchoring of the shell, passes. There are no gills proper to the animal, but their place is

filled by spiral ciliated arms which depend from the region of the mouth, and which are in most cases supported upon a special skeleton or framework ("shelly loop") of shell substance developed in the smaller valve. This arrangement, owing to its tenuity, is rarely preserved perfect, but parts of it can frequently be detected even in the oldest of the fossil shells.

There are but two species of brachiopod likely to be met with in the region a few miles about Camden, the one being the large *Terebratula* (*T. Harlani*) that occurs so abundantly in the shell layer at Stratton's and the West Jersey marl pits, and the other, a smaller species of an allied genus (*Terebratella plicata*), in which the surface of the shell is profoundly plicated.

3. Gasteropoda, or snails, which have the shell made of a single piece, and either in the form of a cone, like the limpet, or a more or less elevated spiral. In many of the so-called naked snails, like the common slug, the shell, a calcareous plate, is very rudimentary, and concealed beneath the mantle. The aperture or mouth of the shell may be continuous—that is to say, round or rounded—or it may be produced anteriorly into a canal of greater or less length. As a rule the round-mouthed species are vegetable feeders, whereas the canaliculated or siphonated ones are carnivorous. The animals of this class possess a head differentiated from the rest of the body, and in this respect, as well as in other points of structure, show a marked advance over the members of the two preceding classes. They are adapted to living both on the land and in the water, and their respiratory organs are accordingly constructed, as the case may be, either on the plan of pulmonary sacs or of true gills.

Most of the gasteropods from the marl occur in the condition

of "casts," or interior moulds, often devoid of distinguishing characters, and hence it is frequently very difficult to determine just where a given form belongs, a difficulty further increased in many cases by the imperfect preservation of the casts. Many of the commoner species, too numerous to be described in detail, are figured on Plate IV.

4. CEPHALOPODA. This, the highest group of the Mollusca, and in some respects the most highly organized of all the invertebrate series of animals, includes the squids and cuttle fishes, which in some form or other are familiar to almost everybody. Except in the case of the argonaut and the pearly nautilus, the body of the animal is naked, there being no external shell. An internal skeleton, generally in the form of a horny pen (gladius) or of a flat calcareous plate (cuttle-bone), is developed on the back of the animal in a fold of the mantle, but of its functions we know practically nothing. Lodged in close proximity to this skeleton, and in some cases abutting against it, we find a peculiar organ, the ink-bag, whose walls secrete the black fluid familiarly known as sepia. The mouth is situated at the extremity of a well differentiated head, and is surrounded by a number, 8–10, of fleshy outgrowths of the body, called tentacles. In the cartilaginous box which envelops the cerebral nerve-centres we have the first appearance among the invertebrates of a brain-case in any way comparable with the skull of the higher animals.

The one form of cephalopod which is particularly abundant in the marl deposits of the State is the belemnite, *Belemnitella mucronata*, a form which is also very largely represented in the equivalent deposits of Europe. The cigar-shaped structure, technically known as the "guard," which is the part commonly found, is in

reality only a portion of the internal skeleton, whose position relative to the body of the animal was the same as that of the horny pen of the squid or calamary. At the broken end the guard usually exhibits a conical cavity (alveolus), into which at one time fitted the chambered body (phragmocone), whose upper surface supported the ink-bag. Anteriorly the guard is continued into a "fore-bone" or sheath (pro-ostracum), but this part of the structure, as well as the phragmocone, is but rarely met with. From such specimens of belemnites as have preserved their soft parts we know that the animal was very closely related to the modern squids, with naked, fleshy bodies, and ten arms, differing from them principally in the characters of the internal skeleton. As in all the existing members of the class, except the nautilus (which has four gills), respiration was effected by a single pair of gills, lodged in a cavity on the posterior side of the body. None of the New Jersey specimens have ever been found in anything like a perfect condition, and not even so much as a trace of the soft parts has as yet been discovered, a circumstance, doubtless, due to the unfavorable condition of the enveloping matrix. To our knowledge no form of belemnite is found outside the Mesozoic—*i. e.*, Triassic to Cretaceous inclusive—series of deposits; hence, the group constitutes an important chronological landmark to the geologist.

Of the four-gilled order of cephalopods, which were provided with a chambered external shell, we occasionally meet with more or less perfect remains of the nautilus (*N. Dekayi*), and of some probably not distantly related forms known as ammonites. In both of these groups the shell consists of a linear series of chambers wound spirally upon itself, the said chambers being held in communication with each other by means of a connecting tube or

"siphon." In the nautilus this siphon passes through approximately the middle of the walls (septa) separating the chambers, whereas in the ammonites it passes along their outer limits, and, therefore, in close proximity to the external surface of the shell. Again, in the nautilus the septal outline is that of a simple fold, or a series of such folds, whereas in the ammonite it is highly complicated by compound infoldings, and appears foliaceous. A form of shell agreeing with the ammonite in the possession of a series of concentric chambers, and in having foliaceous septa, is the baculite ("staff-stone"), but here the chambers instead of being disposed in *spiral* fashion are thrown out in a perfectly straight line, one in advance of the other.

In addition to the shell-fish belonging to the four classes here enumerated we have others very much more minute in structure, individually almost microscopic, which in association form compound colonies. These are the moss-polyps, BRYOZOA, whose fragments are especially abundant in the so-called yellow-sand layer, and whose modern representatives fashion that beautiful cell-tracery on the stones and other hard substances of the sea-shore which so elicits our admiration. The most marked form is the *Pliophlæ sagena*, in whose delicate Y-shaped frame one-third to one-half of an inch in length, the closely-packed cells of the colony can be clearly distinguished even by the naked eye.

Numerous more or less elongated nodules of greensand, having somewhat of a "spongy" appearance, have been described as fossil sponges, but it may be, perhaps, considered a little doubtful whether they do in reality represent tho.e organisms. The sea-urchins are mainly of small size, occurring in most part scattered through the top (or nearly the top) bed of the formation. The spines, and less

often the plates of the test, may be found abundantly in the yellow-sand layer already mentioned, or in the stratum corresponding to it which immediately overlies the shell-layer at Stratton's.

Of the vertebrate life of the period we have already indicated the remains, in the shape of vertebræ and teeth, of members of the shark tribe. Some of these were of formidable dimensions, but in the main they were very inferior to their successors of the Tertiary period. The genus *Lamna*, one of the sabre-teeth, is the commonest form, although the remains of the much more powerful *Carcharodon* are by no means rare. While the fish of the period differed but little from their modern congeners—agreeing, in fact, so closely, as to render difficult the determination of distinctive characters — the reptiles showed a remarkable variation. The remains of ponderous sea-turtles are mingled with those of several species of crocodilians, a true gavial (*Holops*), and the form known as *Hyposaurus*, which differed from the existing crocodile in having both anterior and posterior faces of the vertebræ flat, instead of the one convex and the other concave. The preservation of this character, derived from the class of animals next lowest in rank, the fishes, must be taken as an index of inferiority of organization. In both these forms the teeth were implanted in distinct sockets, and succeeded each other vertically from below upward, so that we frequently find in the jaw-bone the base of one of the teeth harboring the apex of its successor. Formidable though these creatures appear to have been, rivaling, if not fully equaling, in size the largest of the modern *Crocodilia*, they were far surpassed by that group of monsters which were the veritable sea-serpents of the period. *Mosasaurus*, whose huge teeth, measuring four to six inches in

length, and one to one-and-a-half inches in thickness, are not among the uncommon finds of the marl, sported a body fifty to sixty feet in length, and in its noiseless sweep through the sea must have proved the terror of the deep. The extremities of both anterior and posterior appendages were encased in a tegumentary sheath, and thus converted into flippers, very much as in the whale. *Clidastes*, whose proportions were but little, if at all, inferior to those of the *Mosasaurus*, was another member of the same group of the Pythonomorphs, or sea-serpents, whose remains have come down to us.

But of all the strange forms of life that tenanted either the sea or the marshes of the dry land none can compare in grotesqueness of outline, or in the combination of strange characters, with the *Hadrosaurus* and its immediate allies (*Lælaps*). Picture to yourself a species of monster, some 25 to 30 feet in length, with a ponderous frame supported on two very unequal pairs of limbs, very much in the fashion of a kangaroo; a head, four or five feet in length, flattened down in the centre and spread out in front like the bill of a duck, or more nearly, of the spoon-bill; a jaw provided with possibly no less than 2000 teeth, disposed in several series—and you will have some conception of what this ungainly being *Hadrosaurus* was. That it was a vegetable feeder is proved by the structure of the teeth; but just how it managed to grope about the marshes of the sea-coast, whether habitually on all-fours, with its back puffed up in the manner of a cat at bay, or erect, propped up on its hind legs alone, is still a matter of conjecture. Doubtless, however, the erect posture was at least occasionally assumed. Interesting though this creature may appear even from a superficial acquaintance, doubly interesting does it become when we inquire

into its more intimate structure. No one can glance at those huge hind-legs and their terminal appendages without being struck with the resemblance which they bear to the corresponding parts in certain birds. The marked crest on the tibia for the insertion of the muscles of the leg; the disposition of the three toes, the longest in the middle, and the number of phalangeal articulations (joints) to each; and the peculiar conformation of the last joint showing it to have supported a hoof-claw, are approximately the same in the two classes of animals. Looking still further, we find in the structure of the pelvic girdle other no less striking correspondences. If we take such a bird as the ostrich for example, it will be seen that the sacrum or pelvic girdle is an elongated basin-like bone extending laterally on each side of the spinal column. Normally each half consisted of three distinct bones—the ilium, ischium, and pubis—but these have in the course of growth become united or ankylosed together. The pubic bone is, however, still clearly defined in the splint that forms the lower margin, bounding inferiorly the cavity which receives the head of the thigh-bone, and note that it is directed backward. In all living reptiles, on the other hand, this same bone is directed more or less forward, and away from the line of the ischium, whereas in the form under consideration the pubis and ischium assume a course parallel to each other (as in the ostrich), and a position intermediate between that seen in birds and ordinary reptiles. Weighing the several characters which we have here pointed out as separating these animals from reptiles generally, and which ally them with birds, it would really seem, despite the predominance of reptilian characters, as though we were dealing with something that properly belonged neither to the one group nor to the other; in other

words, that we had before us some sort of a connecting link. This view of the relationship of the Dinosaurian reptiles, the group to which *Hadrosaurus* and *Lælaps* belong, has long been maintained by naturalists, and the opinion has been ventured that not unlikely they represent the ancestral form of the keel less, or non-flying birds, such as the ostrich, cassowary, and emu. This view had much to sustain it when it was first promulgated, but it could have received no more striking confirmation than was given to it by the recent discovery of the bird-shaped head[8] to which reference has already been made. Such is the history of this wonderful animal, whose bones lie buried in the clays of by-gone ages. Before its time somewhat similar beasts, leaving in the rock those giant three-toed impressions which for a long time were attributed to birds, prowled over the land-surface, objects far more singular than any now living on the earth.

XI.

PHILADELPHIA BRICK AND COBBLE-STONE; A VISION OF ARCTIC CLIMATES.

Almost everywhere throughout the built-up portion of the city where excavations of one kind or another are being made the pick and the spade disclose the presence of extensive deposits of clay and gravel. These can be readily seen exposed in the cuts of the various railroads leaving the city, in the foundation diggings for houses, and in all places where streams have effected permanent water-courses. Where the gravel and the clay occur together, the latter invariably overlies the former, proving that it was the last to form, and therefore that it is newest in date. In some places the clay has been completely washed away, and we have then only the gravel remaining. This formation of clay and gravel extends back from the Delaware River in an almost continuous sheet for an average distance of some four miles, and the clay itself can be traced up the slopes of the first line of hills to a height of some 150–200 feet. Where the clay is pure, or largely free from sand and gravel, as in the " Neck," or in the region about Nicetown, it is extensively used in the manufacture of bricks, a form of industry that is attested

by the large number of brick-yards lying about. Scattered in greater or less quantities throughout this Philadelphia "brick clay," as the formation is frequently called, are pebbles and boulders of various sizes, mostly well-rounded, and indicating that they had been transported hither through the agency of water. In all cases they have the structure and composition of the rock-masses lying to the north, and we hence conclude that their source lies in that direction. Thus we have boulders of Cambrian quartzite, of Silurian sandrock, and of Triassic shale, formations that are to be met with along the line of the upper Delaware. Some of the boulders measure as much as three or four or more feet in length, but usually they are of very much smaller size. The gravel underlying the brick or boulder clays is of two kinds, a "red" and a "yellow" gravel, the former of which is the newer, and, consequently, the upper one when the two are in superposition. It owes its peculiar color to a ferruginous or iron clay in which the pebbles are imbedded, whose presence conduces to "packing," and renders the gravel eminently fit for the purposes of road-making. Although the predominating material in both the red and yellow gravel is approximately the same—white quartz or quartzite, and less abundantly sandstone, hornstone, and chert—the two can generally be distinguished from each other, apart from the differences presented by color, by the presence or absence of pebbles of red shale, which are very abundant in the former, and wholly wanting in the latter. The yellow gravel, too, is more distinctly fossiliferous, coral and shell-pebbles, indicative of the waste of some Silurian shore-line, being by no means uncommon. It will be observed in many places, as immediately back of the Biological Institute of the University of Pennsylvania, and in the open lots of the upper part

of the city, that the clay is let down into a series of hollows in the red gravel, separating so many crests. Evidently, the water which held the clay in suspension must have, previous to depositing it, scooped out portions of the gravel, for in no other way can we account for this very singular disposition of the material. And this scooping could only have been effected by a sweeping current possessed of an oscillatory or wavy motion. Occasionally the clay is found filling isolated and deeper pockets—"pot-holes"—in the gravel, whose origin might be traced to temporary eddies formed in the stream.

Looking now at the probable history of the gravels and the clays, we must bear in mind certain important facts. In the first place, the clay and the red gravel have been traced for a very considerable distance up the Delaware—the clay, itself, to Trenton and far beyond—and nowhere do they seem to extend very many miles on either side of the river. Similar deposits occur along the Lehigh, and there, too, the clay rises to the 150 foot line. Manifestly enough, streams occupying the present channels of the Delaware and Lehigh, but rising to much higher levels than the modern streams, must have been instrumental in depositing the materials of this DRIFT; this assumption we find borne out by the line of direction which the pebbles took in reaching their destination. The yellow gravel, on the other hand, is not restricted to any marked out water-course, but extends from the Delaware clear through the southern portion of the State of New Jersey, and far down the Atlantic border of the United States. It appears, therefore, to be of oceanic origin. Putting the two series of facts together, we have presented to us, in the first place, the submergence of the land, and the deposition by the sea of the yellow

gravel; secondly, the re-elevation of the land, and the formation of the channel of the Delaware; and thirdly, the great Delaware flood, which swept over the existing lowlands, and threw the boulder-bearing clay to a height of 150 and more feet above the present level of the stream. During the period of submergence the oceanic billows broke within the confines of the State of Pennsylvania, and the greater portion of the site of Philadelphia formed part of the dominions of the sea. When, after the land had again been laid dry through elevation, the northern torrents swept resistlessly on to the sea, the city was again deluged by a sea of water, this time fresh, whose surface rose to an altitude corresponding to the pinnacles of many of our tallest church spires.

What the exact age of the yellow gravel is has not yet been definitely determined, but as it rests in New Jersey upon Tertiary deposits it can evidently not be older than these. Possibly it belongs to the closing period of the epoch. Turning back to our clay and red gravel we might naturally inquire, What could have been the nature of the flood which brought them here? Geologists tell us that in by-gone ages, when climatic conditions were probably very different from what they are now, an enormous sheet of ice, or glacier, covered the greater part of the northern United States east of the Mississippi River; that this continuous ice mass, moving southward, heaped in front of it a long line of earth and boulders similar to that which every Alpine glacier heaps in front of it at the present day, and which geologists technically term a "terminal moraine;" and that after a given period, the "glacial epoch," the ice began to thaw and eventually completely disappeared. Here, then, in the melting of the ice, we have a possible and even plausible source for our southerly trending torrents. Now, what is the nature

of the evidence upon which geologists have based their assumption of glaciation? In the first place, we have the long line of boulders, frequently as much as 50–75 feet in height, and from a few hundred feet to a full mile in width, which, rising and falling with every alternation of mountain and valley, stretches in one almost continuous sweep from the Atlantic half across the continent. The materials of this moraine are indiscriminately heaped together, and in no way appear to be sorted into definite layers. Their rounded surfaces in very many cases indicate that they must have traveled, and this is further proved by the circumstance that in most places the character of the moraine rock is very different from the character of the rock upon which it rests; but in order to have traveled something must have pushed them, and this could only have been either water or moving ice. It is easily conceivable that at one time a vast body of water might have extended into the continent of North America, and formed for itself a beach line co-extensive with the line of the moraine; in so far, no valid objection can be made to the theory which views this *omnium gatherum* of boulders in the light of an ancient beach. But it is not so easy to account for the up and down disposition of the materials, and in fact we know that no beach line could possibly have been formed this wise, creeping up mountain slopes and descending into valleys. We are thus forced to give up the notion which ascribes the building of this barrier to aqueous agencies, and are driven to the alternative of ice action. Whether it was one individual sheet of ice, hundreds or thousands of feet in thickness, traveling over mountain-top and valley, or a more or less close union of several independent streams, which produced the effects before us, it may be a little premature to say; but there are sufficient facts before us to show that ice was

the moving power. We find, for example, that north of the line of the moraine, the solid rock, where laid bare from an earthy covering, is variously grooved and polished, the result of attrition between its surface and rock particles that must have been moved and hard-pressed over it. This same feature is exhibited all through the Alpine glaciated regions, and can there be directly traced to the moving ice and its imbedded boulders, but it is completely wanting south of the line. And in the materials of the moraine itself we meet with numerous boulders showing parallel grooves or scratches, the result of similar attrition under pressure. Evidently, direct ice action extended as far as the line of the moraine and no further. This line, which on the Atlantic border reaches its most southerly point at Perth Amboy, extends thence westward and crosses the Delaware River at Belvidere, a few miles south of the Water Gap. The ice-sheet advanced within about sixty miles of our metropolis, and then halted. Just when this event took place it is impossible to say, but it was, doubtless, a goodly number of thousands of years ago. A time came to pass when the ice melted; torrents of water were given out, which, bursting through the moraine rampart, swept the materials far and wide, and laid the lowlands under a heavy contribution of boulder-debris and mud. These torrents were largely gathered up in the pre-existing water-courses, and such primary streams as the Delaware and Lehigh were swollen to the magnitude indicated by the 150 foot line of clay already several times referred to. Herein we have the origin of the Philadelphia red gravels and brick (or boulder) clay, time-indices of the floods that deluged the country. Large cakes of ice, drifting from their anchorages, doubtless navigated the ice-cold waters, and melting or stranding, deposited the share of rock with which they may have

been freighted. To such transports, probably, do we owe the presence of the larger boulders that here and there lie buried in the clay.

But it appears that the great ice-sheet did not all melt at once; in time the angry waters abated their fury, and a period of former quiescence again set in. The rivers had withdrawn to their legitimate channels, and left their banks to the mercy of those powerful tools which nature employs in carving the earth's surface. Once more the ice melted, and once more the resulting torrents swept resistlessly in the valley of the Delaware. This final thaw was, however, of far less significance, judged by magnitude alone, than the previous one, and its effects appear correspondingly confined to much narrower limits. The newer glacial, or "Trenton," gravel, which is beautifully exposed in long banks a little north of Trenton in the line of the Pennsylvania Railroad, and which in one place in the vicinity of that city has a development of some fifty feet, acquires no special importance about Philadelphia, rising only about twenty-five feet above mean water line. It lies close on the river front, and on Market Street extends up to about Third Street. It forms the floor of the river opposite the city (and as far north as Trenton), and in certain localities, as on Smith's Island and on the bar opposite Cooper's Point, attains a thickness of 100 feet. In a boring recently conducted on Black's Island, a little below Fort Mifflin, the gravel was found to extend to at least 175 feet. Higher up the river, as at Bristol, the gravel, with its topping of light sand, extends fully two miles inland, and in some places still further. Boulders are very numerous in the upper course, and are transported to Philadelphia and elsewhere as "cobble-stones." Apart from its purely physiographical relations the Trenton gravel acquires

special importance from the circumstance of its having yielded, as claimed, the earliest record of man's existence on this continent. Rude stone fragments, very like the chipped implements (palæoliths) left by man of the oldest stone age of Europe, have from time to time been reported from the deposits about Trenton, and if fully substantiated in their character place man coeval with the great northern ice-sheet.

Visitors to the region about Chestnut Hill, Bryn Mawr, Haverford, Coopertown, and elsewhere on the high ground, will have noticed, at elevations of from 300 to 450 feet, patches of a rusty-looking pebbly or gravelly deposit, very different from anything that we have thus far seen, and much resembling in places an artificial compound. The individual pebbles of quartz are largely cemented together into a coarse iron conglomerate, which sometimes rings when struck with a blow of the hammer. Very little of this gravel is found in the lowland, and where so occurring is derived as a down-wash from the upper region. Patches of the same material, on the other hand, are met with on the lowland hills of New Jersey, as about Mount Holly, and on the slopes of the Highlands of Sandy Hook, where in both cases they cover strata of Cretaceous age, and are thus proved to be of a newer date. Further south along the Atlantic border the line of gravel, always occupying a high position, can be traced beyond Wilmington to Georgetown Heights, District of Columbia, and deep into the Southern States. It is more than probable that the disjointed patches of this "Bryn Mawr gravel" or "Mount Holly conglomerate," at one time formed a continuous whole, which has gradually been reduced to its present condition through the effects of erosion. The formation is undoubtedly of marine origin, and

as we have already been taught that a pebbly deposit indicated littoral conditions, we must conclude that it is in the nature of an ancient shore-line, or beach. But of what age? We have already determined it to be post-Cretaceous, and it can, therefore, only be Tertiary or post-Tertiary, more likely the former, seeing the amount of erosion it has suffered. Nearer to the sea the deposits of equivalent age are probably represented in some of the clays and sands that cover the lowland strip.

Such, in brief, is the wonderful history which the gravels, clays, and cobble stones of Philadelphia reveal to us—a history which cannot fail to sharpen the edge of even the most dormant intellect. The mind wanders back to a period, possibly long antecedent to the advent of man, when oceanic conquests extended far within the boundaries of our forest State; when the Atlantic billows swept the crests of our most elevated hills, and when the heights of Chestnut Hill, Bryn Mawr, and Media echoed back the roar of the breaking surf. The beach-line of upland gravel was then deposited. Southern New Jersey, which had already added its mite to the formation of the continent, lay at this time buried beneath the sea, and had again to be; from its submerged surface occasional prominences probably rose out of the water, forming islands, some of whose positions may still be indicated in such lowland hills as the Sandy Hook Highlands and Mount Holly. The land now began to rise, but before New Jersey had finally and completely emerged from the deep, the ocean deposited the yellow gravel. The site of Philadelphia was made part of *terra firma*, and by its side was dug the channel of the Delaware, which had before debouched not far from the city of Trenton. The marine fauna of the coast was then the same as now, and even on the land the animals were very little

different; a few uncouth forms still wandered among the many, strangers to the flock. In the meantime certain physical conditions, but little understood, had gradually prepared the way for the accumulation in the north of a vast ice sheet, which advanced southward to within about sixty miles of the city, and whose melting produced those prodigious floods whose effects are portrayed in the deposits of the now familiar gravel and clay. The greater part of what is city was buried beneath water of icy-coldness, and icebergs of no mean magnitude traversed the region of the present church-spires. The reindeer and mastodon, precursors of the storm, had wandered with the climate south, and left in their bones the tale of northern winters. Man either had appeared, or was to appear; not, however, the civilized man of to-day, but the feeble-minded savage, who fashioned rude stone implements, and who had possibly only recently acquired the use of articulate language.

The ice finally disappeared, the waters were called back to their channels, and the landscape rose resplendent in its modern garb.

The traveler to the city who sees the gravels swiftly fleeting before the windows of his railway carriage; who laments the singularly unpretentious appearance of the outlying brick-yard clays; and who ruthlessly treads the much, and justly, despised cobble-stones of our thoroughfares, little thinks what history these commonplace objects unfold. They stand as monuments of a history far more wonderful than any written in book, and will continue to so stand probably long after man will himself have disappeared from the scene.

NOTES.

1 (p. 7). In addition to the 6,700,000,000 cubic feet of sediment freely suspended in the water the river pushes along on the bottom a quantity of mud equal to 750,000,000 cubic feet, so that the total quantity annually discharged at its mouth is about 7,500,000,000 cubic feet.

2 (p. 8). More recent calculations make the elevation of the North American continent nearer 1000 feet.

3 (p. 38). No fossils properly belonging to the rock-masses; fossiliferous pebbles of a much newer date, on the other hand, are quite abundant in some localities.

4 (p. 57). It is important to note the particular feature in a landscape which a given formation typifies; its extent and boundaries may then be much more readily traced.

5 (p. 59). Not everywhere. The scarcity of Cambrian fossils in the State of Pennsylvania as compared with some other regions is very surprising, and has not yet received its proper explanation.

6 (p. 71). Throughout a considerable part of the valley the limestone is overlaid by a heavy deposit of iron-bearing clays, which are evidently derived from the dissociation of the surrounding rock masses. The ore (limonite), which is extensively "mined," appears to belong to several distinct periods of formation, some of it, probably, being as late as Tertiary.

7 (p. 90). Under normal conditions of pressure; the intense pressure exercised by the outer mass of the earth upon the interior prevents liquefaction where it would otherwise obtain.

8 (p. 124). The head here referred to belongs to the genus *Diclonius*, of the family *Hadrosauridæ*, a form very closely related to *Hadrosaurus*, and identical with it in most respects.

CORRECTIONS.

P. 30. In place of *Massachusetts Bay* (third line from bottom of page) read *coast of Maine.*

P. 38. For *Yardleyville* read *Langhorne.*

P. 40. For *Columbia Avenue bridge* read *Columbia bridge.*

P. 49. For *iron deposit* (seventh line from top of page) read *iron and manganese deposit.*

EXPLANATION OF PLATES.

* Where not otherwise indicated the species are Cretaceous: the Foraminifera very much magnified.

Plate III.

Fig. 1.	Tooth of Mosasaurus.	(Pythonomorph).
2.	" Thoracosaurus.	(Crocodilian).
3.	" Gavial.	"
4.	" Hadrosaurus.	(Dinosaur).
5.	" Hyposaurus.	(Crocodilian).
6.	" Bottosaurus.	"
7.	" Pristis. (Eocene?)	(Saw-fish).
8.	Fragment of jawbone and tooth of Bottosaurus.	
9.	Tooth of Galeocerdo.	(Shark tribe).
10.	Vertebra of Crocodile.	
11.	" Hyposaurus.	(Crocodilian).
12.	" Mosasaurus.	
13.	Rapier of Cœlorhynchus. (Eocene?)	(Sword-fish).
14.	Part of dermal armor of Crocodile.	
15.	" " " Turtle.	
16.	Triassic foot-prints.	
17.	Tooth of Notidanus.	(Shark tribe).
18.	" Hemipristis.	"
19.	" Lamna.	"
20.	" Enchodus.	(Bony fish).
21.	" Xiphodolamia.	(Shark tribe).
22.	" Carcharodon. (Eocene?)	"
23.	" Otodus.	"
24.	" Lamna.	"
25.	Triassic foot-print.	
26.	Clidastes.	(Pythonomorph).

Pl. III.

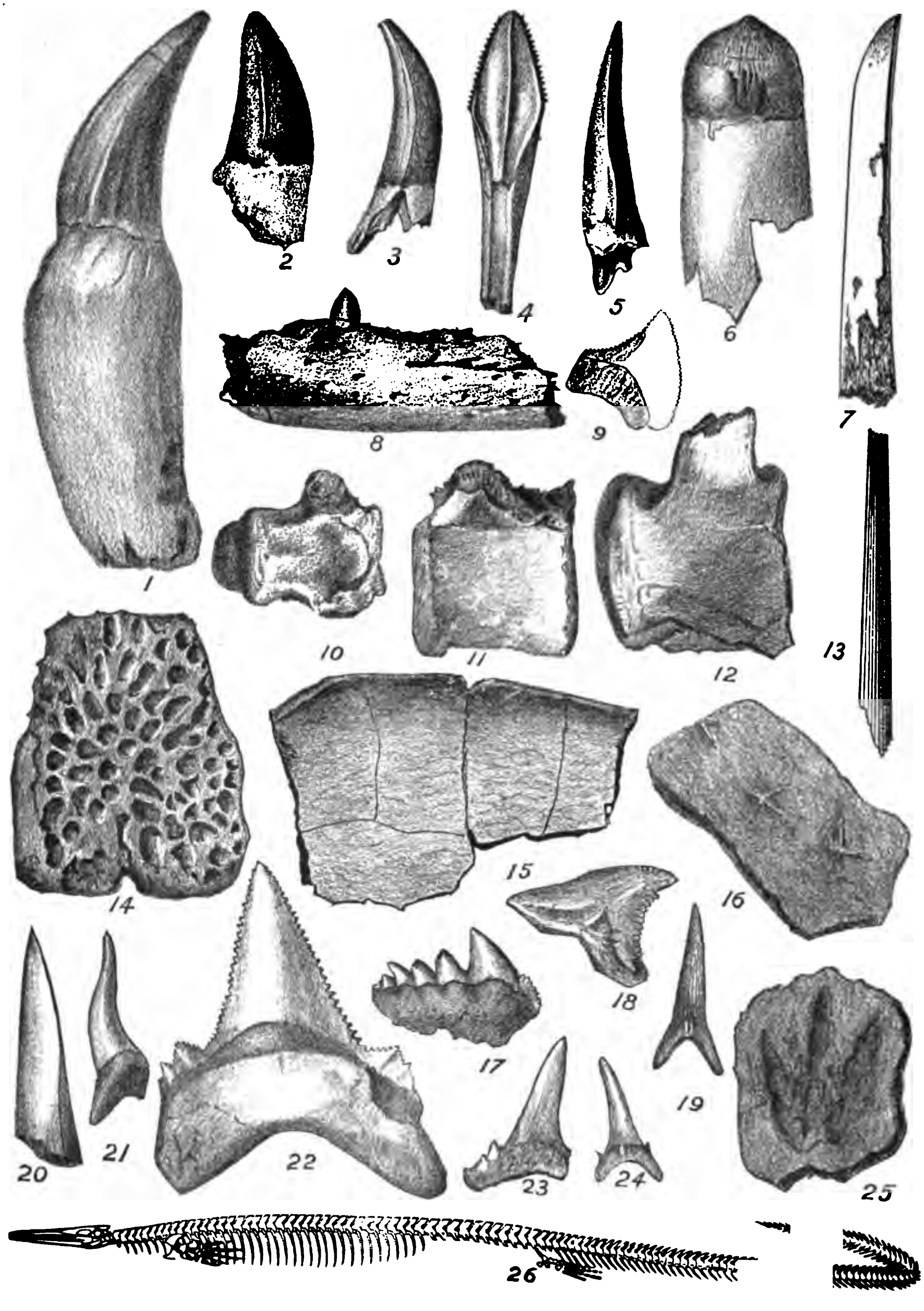


Plate IV.

Fig.	1.	Vertebra of Shark.	
	2.	Teeth of Myliobatis. (Eocene?)	(Ray tribe).
	3.	" Pycnodus.	(Ganoid).
	4.	Scaphites Cuvieri.	(Cephalopod).
	5.	Baculites ovatus.	"
	6.	Scaphites Conradi.	"
	7.	Ammonites placenta.	"
	8.	Belemnitella mucronata.	"
	9.	Nautilus Dekayi.	"
	10.	Ammonites Delawarensis.	"
	11.	Natica abyssina.	(Gasteropod).
	12.	Actæonina (cast).	"
	13.	Pteroceras "	"
	14.	Anchura (Rostellaria) pennata (cast).	"
	15.	Pliophlæ sagena.	(Bryozoan).
	16.	Cast of Turritella.	(Gasteropod).
	17.	Anchura (Rostellaria) pennata (cast).	"
	18.	Pleurotomaria Abbotti. "	"
	19.	Voluta Conradi. "	"
	20.	" nasuta. "	"
	21.	" biplicata. "	"
	22.	Rapa elevata. "	"
	23.	Natica Halli. "	"
	24.	Terebratula Harlani.	(Brachiopod).
	25.	Fusus retifer.	(Gasteropod).
	26.	Phasianella punctata.	"
	27.	Actæonina naticoides.	"
	28.	Phorus leprosus.	"
	29.	Bulla (cast).	"
	30.	Terebratella Sayi (plicata).	(Brachiopod).
	31.	Terebratula Harlani.	"

Pl. IV

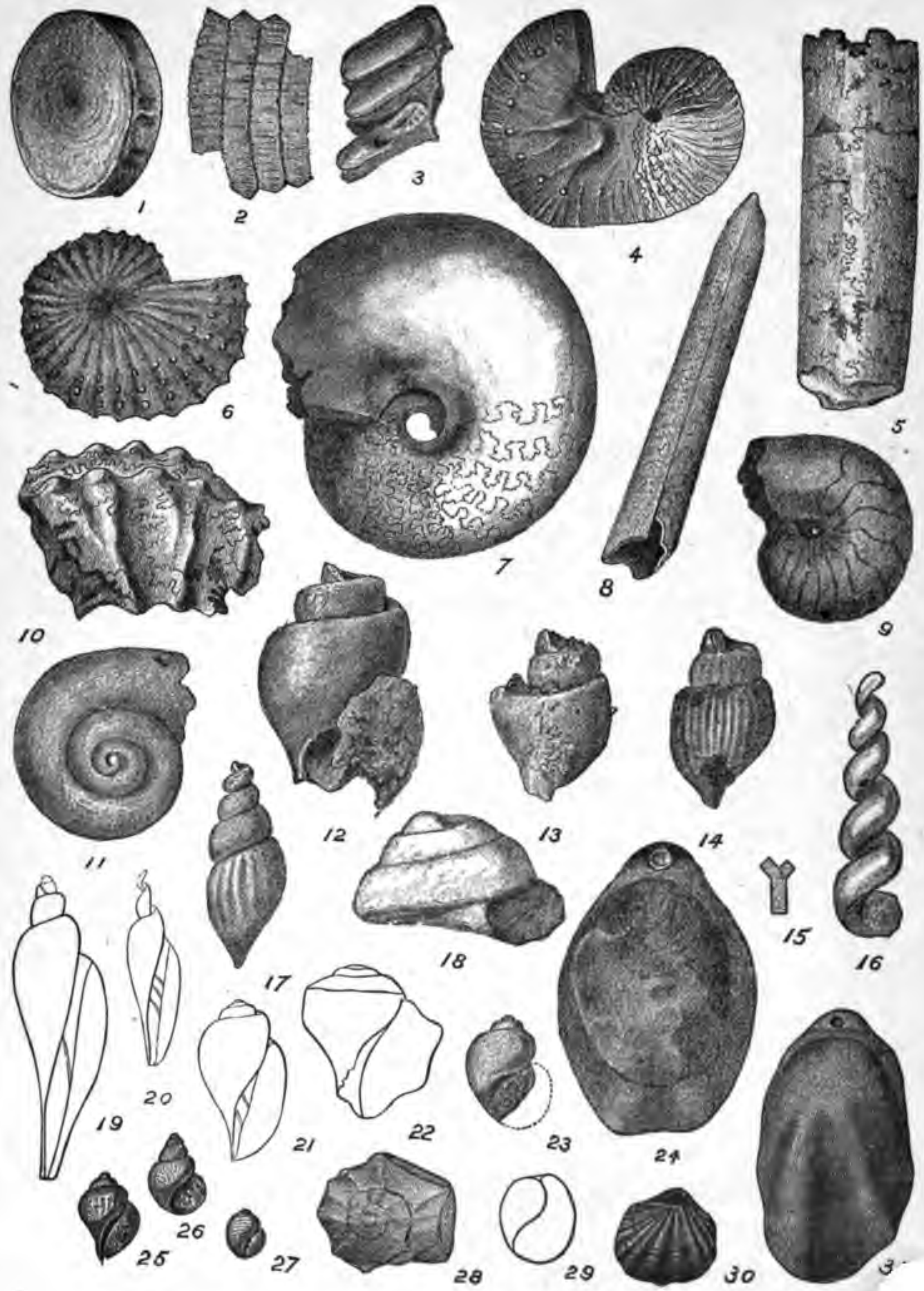

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

Plate V.

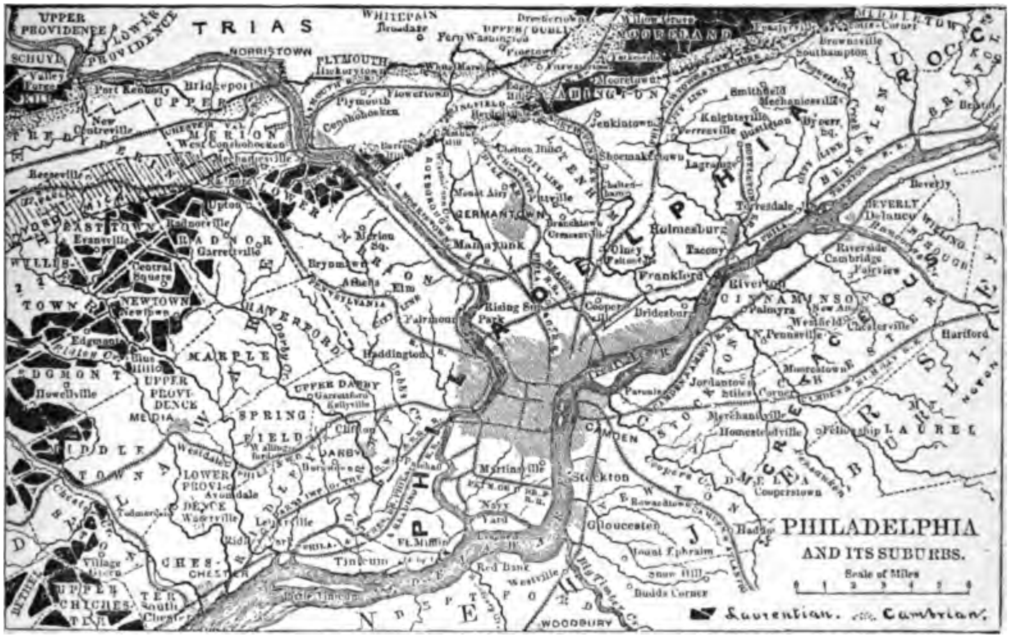
Fig. 1.	Ostrea larva.	(Lamellibranch).
2.	Gryphæa vesicularis.	"
3.	Veniella Conradi.	"
4.	Ostrea larva.	"
5.	Pecten.	"
6.	Exogyra costata.	"
7.	Modiola.	"
8.	Modiola ovata.	"
9.	Gryphæa vomer.	"
10.	Leda pinnaforma.	"
11.	Arca vulgaris (cast).	"
12.	Arca quindecemradiata.	"
13.	Inoceramus Barabini (Cripsii).	"
14.	Cardita subquadrata.	"
15.	Crassatella Delawarensis.	"
16.	Leda.	"
17.	Crassatella Monmouthensis (cast).	"
18.	Leda.	"
19.	Trigonia thoracica.	"
20.	Cytherea Delawarensis.	"
21.	Impression of shell in Triassic shale.	
22.	Mysia gibbosa.	(Lamellibranch).
22 a.	Pholadomya (not numbered).	"
23.	Gastrochæna Americana.	"
24.	Spines of Urchins.	(Echinoid).
25.	Teredo tibialis.	(Lamellibranch).
25 a.	Teredo irregularis (not numbered).	"
26.	Impression of shell in Triassic shale.	
27.	Polymorphina subrhombica.	(Foraminifer).
28.	Globulina globosa.	"
29.	Cristellaria Baylei.	"
30.	Button (plate) of Urchin.	(Echinoid).
31.	Hemiaster parastatus.	"
32.	Nodosaria polygona.	(Foraminifer).
33.	Dentalina confluens.	"
34.	Rotalia Mortoni.	"
35.	Rosalina ammonoides.	"
36.	Truncatulina Dekayi.	"
37.	Cardiaster cinctus.	(Echinoid).
38.	Nucleolites crucifer. (Eocene?)	"
39.	Echinobrissus æquoreus.	"
40.	Faujasia (?) florealis.	"
41.	Dentalina colligata.	(Foraminifer).
42.	Bulimina tortilis.	"
43.	Cristellaria intermedia.	"
44.	Robulina trachyomphala.	"

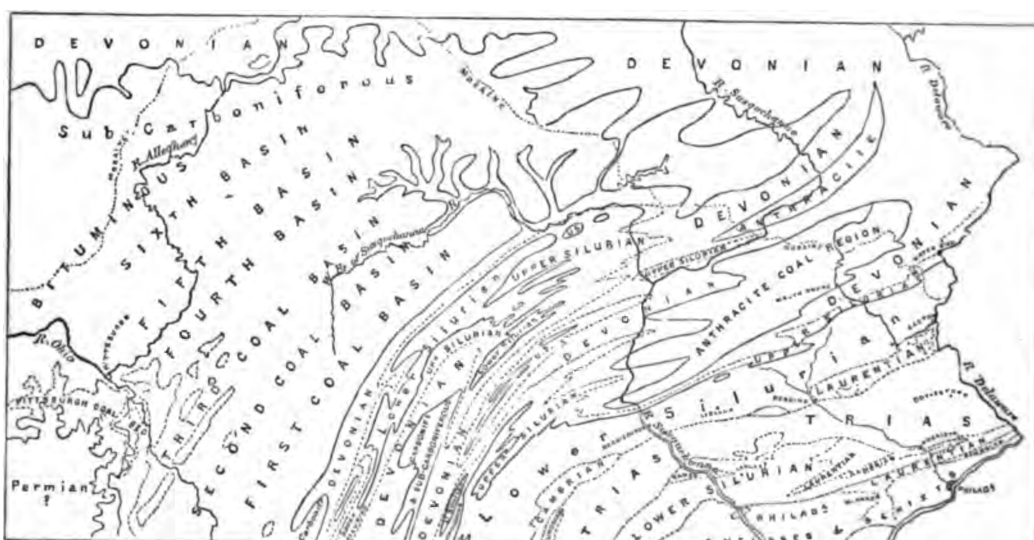
Pl. V


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44

HADROSAURUS FOULKII.

(EXTINCT REPTILE FROM NEW JERSEY.)





GEOLOGICAL SKETCH MAP OF PENNSYLVANIA.